VOLUME XXXII NUMBER 5

BOTANICAL GAZETTE

NOVEMBER, 1901

NEW OR LITTLE KNOWN UNICELLULAR ALGAE.

II.—EREMOSPHAERA VIRIDIS AND EXCENTROSPHAERA.

GEORGE THOMAS MOORE.

(WITH PLATES X–XII)

Eremosphaera viridis.

AMONG the many algae which have been supposed to represent stages in the life history of other plants, perhaps none have had such a variety of positions ascribed to it as the beautiful spherical form known as *Eremosphaera viridis*. This species was described by De Bary in 1858 in his *Untersuchungen über die Familie der Conjugaten* as a desmid, although he had not observed anything resembling conjugation in the plant, and could only determine its affinities by the mode of division and its general similarity to other well known desmid forms. About the same time, Henfrey (5) found this unicellular organism in bogs in Northumberland, and described it as *Chlorosphaera Oliveri*. A good account of the general structure of the plant is given, and because of certain appearances which he assumed to be antheridia, Henfrey says "in the vicinity of Oedogonieae they (Chlorosphaera) will find their true place." Hofmeister (6), who described Eremosphaera in his memoir on the Desmidiaceae and Diatomaceae, without giving it a name, regarded it as a link between the Desmidiaceae and Palmelleae.

Twenty-five years later De Wildeman in a measure confirmed the view of De Bary, but stated that Eremosphaera

more probably belongs to some developmental stage of a desmid, possibly a zygospore, than represents the vegetative condition of any unicellular alga. More recently De Toni (3) describes the genus as an exceedingly doubtful one, suggesting that the large cells resemble fern prothallia, and that we may expect to find it related to the higher cryptogams. Wille (7), in Engler and Prantl, places Eremosphaera among the Pleurococcaceae. The last investigator to have had this alga under consideration is Chodat (1), who believes that its affinities are such as to put it with the Volvocaceae; furthermore, the results of his observation show a condition of polymorphism which has not hitherto been suggested. In addition to the regular vegetative condition and the ordinary methods of multiplication, which will be described later, Chodat found a number of transition stages which he variously designated as "Gloeocystis" forms, "Palmella" forms, "Schizochlamys" forms, "Centrosphaera" forms, etc. According to Chodat, these various stages of Eremosphaera are actually the same thing as the genera which they resemble, and we can no longer recognize them as distinct species, but must include them all under the single name *Eremosphaera viridis*. It was with the desire to clear up the question as to the polymorphism of this form, and to settle, if possible, its life history and affinities, that the investigation concerning this alga was undertaken.

MATERIAL.

The specimens first studied were secured from a small pool formed by a sluggish brook running through a marsh near Ridge hill, Mass. Although the pool is quite small, there is usually plenty of water, and at no time during the year is the material absent from this locality. There was no sphagnum growing in the pool, as seems usually to be the case where Eremosphaera is found, but an abundance of Zygnema, Spirogyra, and other Conjugatae, notably Micrasterias, was frequently present. The plants were first discovered in May 1897, when they numbered about twenty to the cubic centimeter. Since that time they

have been collected during almost every month of the year, always in considerable quantities.

In August, 1899, while on Naushon, one of the Elizabeth islands, near the place on the east shore known as Tarpaulin cove, Eremosphaera was found in its typical habitat, namely a low sphagnum swamp. There was practically no difference between the forms from the two localities except that of size, and this was quite characteristic. Out of the two hundred and fifty measurements of the specimens from Ridge hill (*fig. 1*), the average diameter was 75.45μ with a maximum of 105μ and a minimum of 67.5μ; while of the same number of spheres from Naushon (*fig. 3*) the average diameter was but 35μ with a minimum of 31.5μ and a maximum of 40.7μ. The figures above referred to will give a fair idea of the comparative sizes of the two lots of material.

This marked difference in size has been noticed by Chodat (1), who in the spring of 1892 found Eremosphaera which was almost exclusively the large form, while in 1894 he discovered among Sphagnum and Carex a quantity of the small variety. The relative sizes of these two extremes is not given, except for the statement that by careful search one might find "giant individuals" of 170μ. De Bary, in his original notice of the plant, gave the measurements as about 60μ, while Rabenhorst says 43–49μ. Kischner gives 100–145μ, and De Toni covers both extremes by citing 100–150μ, as the usual size, 30–80μ specimens being occasionally found. It is evident, then, that the plant is one varying within wide limits. The maximum of the Naushon form not coming within 26μ of the minimum of the Ridge hill form, if size be a sufficient criterion there would be no difficulty in recognizing a variety *minor*, measuring from 30–41μ, and a variety *major*, measuring from 67–100 or more microns. There can be no question that the smaller forms, found by me at Tarpaulin cove, were mature plants. The arrangement of the chromatophores and general cell contents was in every way identical with the larger forms, and division took place as readily in cells 33μ in diameter as in those measuring 100μ. Furthermore,

cultures grown from material from the two localities have retained their characteristic size through a cultivation of more than eighteen months in one case, and for over three years in the other.

GENERAL STRUCTURE.

In appearance Eremosphaera resembles a perfect gelatinous sphere with numerous minute chromatophores usually lining the wall. The arrangement of the chromataphores varies greatly, hardly any two specimens showing exactly the same pattern. Usually they are scattered about in an irregular fashion, sometimes singly, sometimes in groups (*fig. 1*); or they may radiate from the center in a quite definite manner (*fig. 10*). That light has much to do with the arrangement of the color-bodies may be seen from *fig. 4*. This specimen while kept in subdued light showed a cell of almost solid green hue, so thickly were the chromataphores lining the wall. After five minutes in bright sunlight, however, the condition shown in *fig. 4* was obtained, and in watching the effect under the microscope the chromatophores could be seen sliding along the protoplasmic strands which radiated from the centrally placed nucleus.

When the chromatophores are at the periphery of the sphere and are not too great in number, the nucleus is easily recognized without the aid of stains. The method recommended by Chodat (1) of clearing with chloral solution and staining with carmine brings it out well, and also reveals one or more nucleoli (*fig. 2*). At times the nucleus and the protoplasmic mass surrounding it become quite granular, giving the appearance of some foreign body within the cell. The strands which radiate from the nucleus connect with the protoplasm lining the cell wall and form quite a complete network (*fig. 5*).

The chromatophores are irregular both as to outline and as to size, varying from circular, through broadly elliptical, to narrow fusiform (*fig. 16*). Occasionally they are angular, of a rhomboidal outline, a type especially common in the variety *minor*. The honeycomb appearance described by Chodat (1)

was not visible in my material, neither was the platelike expansion which he says is drawn out from the middle of the chromatophore and may consist of two or three bent wings, causing an irregularly shaped dark spot in its center. A good sized pyrenoid is always distinctly visible, there being sometimes as many as three or four in each chromatophore. If the chromatophore be treated after the manner of Mayer, first adding a dilute iodine solution and then chloral hydrate, the crystalline structure of the pyrenoid is easily seen (*fig. 18*), and the layer of starch surrounding it made visible.

The wall of Eremosphaera is normally thin and of but a single layer in thickness, but it has the property of great gelatinization, and is often laid down in successive layers. This condition gives rise to the forms characterized by Chodat as the Gloeocystis, Palmella, and Schizochlamys stages. The duplication of the wall does not seem to be confined to particular periods of development, but may occur at any time. Each wall soon becomes separate and distinct from the adjoining ones, and with care the several coats may be broken one at a time and the contents allowed to slip out. That such forms are really what botanists recognize as Gloeocystis or Schizochlamys is doubtful. While it is possible that Emerosphaera, surrounded by a number of gelatinous walls, might be mistaken by a hasty observer for a similar condition in either Gloeocystis or Schizochlamys, it does not necessarily follow that these genera are one and the same thing. Schizochlamys, I have been able to cultivate for a considerable length of time, and it has never exhibited any evidence of being related to Eremosphaera. Since we can have the same duplication of the wall in Chlamydomonas and other genera widely separated from the ones under discussion, it hardly seems a sufficient basis upon which to unite a number of forms frequently showing marked differences in their life histories.

In addition to the successive formation of coats around Eremosphaera, there sometimes occur peculiar growths on the inner surface of the wall, which are the result of a number of layers of cellulose being formed about a central point (*fig. 11*).

These concentric layers can occasionally be separated by crushing, but usually they are very compact. They project inward towards the center of the cell, and in case a second continuous wall is formed, it remains indented wherever these excrescences appear. As many as twelve secondary walls have been counted around a single sphere, and there seems to be no limit to their formation.

CULTURE METHODS.

A plant which has had as many developmental stages ascribed to it as Eremosphaera naturally necessitates the most careful application of pure culture methods. Consequently the cultivation of this plant was attempted as soon as it was procured, and cultures have been kept running successfully for about three years. As it was not convenient to visit the original locality frequently, and to obtain fresh material in that way, it seemed best to maintain a number of gross cultures from which pure transfers might be made at any time. No trouble was experienced in this, and water from the original pool, containing diatoms, numerous filamentous algae, and Eremosphaera, has been kept continuously in the laboratory. Bacteria appeared for a short time, but the water soon cleared, and all the algae have maintained themselves in good condition. These gross cultures were kept either in crystallizing dishes or wide-mouthed bottles, over which was a sheet of glass to prevent too rapid evaporation. It was found that the crystallizing dish was most convenient for this purpose because of the ease with which material could be picked out from it. The large Eremosphaera cells were readily found with a hand lens, and then transferred by means of a pipette to a watch glass. Here they were washed several times in sterilized water, and then examined under the microscope, before being placed on the culture medium.

Various methods of cultivation were tried. The well-known solution of Knop was used in strengths from 0.2 per cent. up to 1 per cent., both as a fluid culture and in connection with agar agar and gelatin. The gelatin was soon abandoned, however, on account of the low temperature at which it liquefied, since

agar agar (5 to 7 grams to the liter of nutrient solution) enabled one to keep perfect trace of the cells, and was more satisfactory for many reasons. Stender dishes were used for culture vessels because it was desirable to have as large an amount of the medium as possible, so that the cultures would last for some time, and in order that there might be a considerable surface for growth. The same precautions of sterilization were observed that would have been necessary for bacteriological work, and check cultures indicated that these methods were successful.

Usually after sterilization there would be a considerable amount of moisture collected upon the surface of the agar, and it was in this fluid that the Eremosphaera cells were deposited. If placed directly upon the surface of the agar it seemed impossible for them to persist, but when transferred to the moisture and then gradually, through the evaporation of the superfluous liquid, brought in contact with the nutrient agar there was no difficulty in making them grow as well as in fluid media.

Van Tieghem cell methods were not successful. The plants lived for a considerable length of time and the chlorophyll granules moved under the influence of sunlight, but there was no development of any kind. Cultures kept in tightly sealed cells for several months would gradually present an appearance resembling the formation of spores, and at first this was thought to be the case. Upon investigation, however, it was found that this effect was due entirely to the rounding off of the chromatophores, which were closely packed at the periphery of the sphere. Upon being restored to natural conditions such cells resumed the characteristic arrangement of the color bodies, and the nucleus at no time presented any other appearance than that found in the normal plant.

Ward cells, which allowed a constant supply of air and yet prevented any contamination from the outside, were partially successful. The most satisfactory method for making direct observations of cultures, however, was to isolate a single individual and place it on a slide either in sterilized water or a nutrient solution. A large cover-glass was then placed over it, being

propped up by three or four minute drops of a mixture of bees-wax and vaseline. A bell jar lined with moist filter paper was sufficient to prevent the evaporation of the solution for twenty-four hours, and a drop of nutrient fluid added at one side of the cover-glass replaced any loss during the examination under the microscope. Such cultures require daily examination, of course, but when the life history of an organism is being followed out this is an advantage rather than an objection. The wax supports for the cover-glass were preferable to bits of glass or filter paper because they permitted the crushing out of a specimen, if necessary, and held the cell in just the desired position. Cultures of this kind gave the best of results, the algae apparently developing in a perfectly normal manner.

MULTIPLICATON AND DEVELOPMENT.

De Bary, in his observations upon Eremosphaera, discovered that it multiplied by simple division into two or four cells, each of which soon attained the size of the original plant. Henfrey likewise recognized this condition. Such a division is accomplished by the formation of a new wall between the two halves of the original cell. This wall extends completely around each half, and as the nucleus divides and the chromatophores, with the protoplasm, form into two irregular masses, the gelatinous wall pushes in from the periphery, forming the division (*fig. 6*). The two cells thus formed gradually increase in size, so that in a short time the original wall is ruptured and the daughter plants are liberated. These usually escape as perfect spheres, but may retain their flattened appearance for a short time, as is shown in *fig. 7*. More rarely a second division may take place at right angles to the first, thus producing four daughter cells instead of two (*fig. 8*). Wolle (**8**) and Chodat (**1**) both speak of even further successive divisions, but my material has never shown more than four cells formed in this way.

This method of simple division has been believed to be the only means of propagation in Eremosphaera, and it was not until the result of the researches of Chodat became known, that

a more complicated life history, including the formation of zoospores, was suspected. Henfrey, in his discussion of the plant already referred to, suggested the possibility of antherozoids, but this condition was undoubtedly due to the presence of some parasite, which Henfrey himself recognized as a possible cause.

While considerable doubt has been cast upon Chodat's interpretation of what he saw, the fact that certain of the stages which he describes certainly exist in material found in this country, makes it necessary that a most careful search be made for all the forms supposed by him to be connected with Eremosphaera. In addition to the well-known division into two or four spheres, Chodat (1) describes a kind of sporangium-building condition where division goes on until the diameter of the ultimate cells is ten to twenty times smaller than at first. This stage I have been unable to find, and nothing of the sort seems to occur in the material I studied, either in gross or pure cultures. In addition to these non-motile spores, Chodat describes ciliated spores. Just how and when these may be formed is not clear, but it is to be inferred that they arise from some "palmella" condition and not directly from the adult plant. These zoospores, according to Chodat, are usually elliptical, and are always surrounded by a gelatinous coat, reminding one of certain forms of Chlamydomonas. Each zoospore has a red eye spot, a radiating chromatophore, and an evident nucleus. In most cases there are two cilia, but exceptionally three. The question as to whether they actually had four remained undecided, as did also the possibility of their conjugation. They seem to have been irregular both as to size and shape, for Chodat (1) says, "da ihre Mutterzellen an Grosse sehr verschieden sein konnen, so sind infolgedessen die Zoosporen auch sehr verschieden, sowohl was die Grosse als auch die Form anbetrifft."

Although a most careful search has been made among material growing under all conditions, not the slightest trace has ever been discovered of any motile spore in evident relation to Eremosphaera. Occasionally plants would be found of a lighter

green color, filled with spherical bodies (*fig. 13*), which in general resembled a sporangium. But while these cells were observed daily for weeks they not only failed to show any signs of further development, but gradually disintegrated instead. After having observed algae which were crushed and noting the manner in which the chromatophores formed a colorless membrane about themselves, with the green collecting at one side, as in *fig. 17*, it would seem almost certain that the conditions I had been observing were due to injury, and the admission of a small amount of water caused the abnormal appearance suggesting spores. On one occasion, a plant of this sort showed four or five biciliate organisms within it, which at first were supposed to be zoospores (*fig. 14*). Their subsequent development (*fig. 15*), however, proved them to have no connection with the alga, and after three days, when the culture was crushed out, it was found that the organisms possessed no chlorophyll, a fact which could not be made clear with certainty while they were embedded among the chromatophores.

Failing to find zoospores under natural conditions, it was hoped that some change in the environment might be produced which would cause zoospore formation. Plants, closely encysted in numerous gelatinous coats and which had been growing in a nutrient solution, were removed to fresh water and to variously modified media. Some cultures were allowed to remain in the sunlight, others were kept in darkness. Specimens taken direct from nature were placed in numerous solutions and subjected to all possible changes of temperature and moisture. Aeration was tried for lengths of time varying from a few hours to several weeks, and cells were kept on ice over night, and then gradually brought into the temperature of the laboratory. But none of these methods yielded any thing more than the previously described method of division. Consequently, after having had cultures running for over three years, and making repeated examinations of material collected under natural conditions, it must be said that at no time was there any appearance which gave the slightest evidence of zoospore formation, and it

is certain that in the forms found growing in this country zoospores must be very rarely, if ever, formed.

The rejuvenescence described by Chodat (1), wherein a cell instead of dividing simply slips out from the old sheath, was frequently seen and is represented in *fig. 5*. Whether this can really be termed a rejuvenescence, according to the ordinary use of the term, is a question. It seems as though this condition can hardly be different from those which show a succession of walls, except that in the first case the outer wall is not strong enough to hold the cell, and it slips out as indicated. There never appears to be any change in the contents of the cell, not even in the arrangement of the chromatophores.

In the mud at the bottom of the water containing Eremosphaera, there will usually be found a considerable number of resting cells. These are of the typical brick-red color, and generally show successive layers of sheaths. They contain large quantities of oil, and in no way appear to differ from the same type of spore in other algae. So far as observed, the development of the resting spore was not accompanied by the formation of any new cells. The red color was gradually lost, the chromatophores became more and more prominent, and the normal vegetative appearance of Eremosphaera was the result. Usually the resulting cell is quite large and division takes place in a very short time. No division of the resting spores was observed, the condition indicated in *fig. 19* being an example of where two cells passed into the resting condition almost immediately after division, and before they had time to enlarge. This is not an infrequent occurrence.

TAXONOMIC POSITION.

It is evident from the foregoing that there is no reason for supposing that Eremosphaera is related to the desmids or to any of the Conjugatae; neither does it seem possible to show that it forms any part of the life history of any of the higher cryptogams. The theories of Henfrey (5) and Hofmeister (6) may also be dismissed, so that there only remain the two positions

ascribed to it by Chodat (1) and Wille (7). Chodat, as the result of his study of Eremosphaera, came to the conclusion that it had evident affinities with the Volvocaceae, and if all the stages described by him are really passed through by this plant, it would seem as though some such disposition would have to be made of it. On the other hand, the negative results of my cultures and observations would seem to throw some doubt upon its supposed polymorphism, particularly with regard to a motile stage. It seems, therefore, that for the present at least, Eremosphaera should be classed with the group of green algae possessing no zoospores, namely the Protococcoideae.

Excentrosphaera, nov. gen.

There still remains to be discussed the form described by Chodat as the "Centrosphaera" stage. This form was present in small quantities in the first material collected at Ridge hill, and was immediately separated from the Eremosphaera cells and cultivated. The growth was luxurious in fluid nutrient media, and satisfactory, if not so abundant, on agar. In addition to these pure cultures, a number of dishes containing water from the pool which supplied the original material were kept in the laboratory, and in the course of a few months became filled with a large number of these plants. The conditions for growth under these various circumstances seemed favorable and normal, but there was at no time any evidence of the slightest connection with the developmental history of Eremosphaera. After having had this form under cultivation for about three years, and having seen it pass through its life cycle over and over without assuming a stage which in any way resembled those of Eremosphaera, I am obliged to conclude that it is an independent genus. Since it does not seem to have been described elsewhere, the name *Excentrosphaera viridis* has been given to this alga.

Excentrosphaera, in its mature condition, may assume an outline varying from that of a perfect circle, through all gradations to an ellipse, as well as occasional excentric and indefinite shapes. The general resemblance to the forms assumed by germinating

Ulothrix spores is striking, but the much larger size, the arrangement of the chromatophores, and suosequent development make it an easy matter to differentiate this plant from that genus.

The numerous large chromatophores are crowded near the surface of the cell, and are usually arranged radially (*figs. 21, 23, 24*). As the cells assume irregular shapes the chromatophores may be distributed in various ways, and there are often lacunae between the chlorophyll masses. Sometimes there are several layers of chromatophores, so that except for the nucleus and a small amount of protoplasm, the cell is almost filled with these bodies. There are numerous minute pyrenoids in each chromatophore, but these are not readily made out without the use of stains. The densely packed chromatophores render it difficult to see the centrally placed nucleus, with its nucleolus, but sections (*fig. 25*) or crushing will usually reveal it. When the cells are about to form spores the nucleus divides repeatedly (*fig. 26*), then the chromatophores break up, and in a short time the entire cell has a homogeneous appearance similar to that shown in *fig. 27*. The spores, which are formed from this condition simultaneously, are 2–3μ in diameter, non-motile, and without a red spot. They escape through a hole formed by the dissolution of the wall (*fig. 22*), and in about a month increase to the size of the mature plants. The developing spore usually remains spherical until it has reached its maximum size, and not until then does it begin to take on the irregular shape previously referred to.

The wartlike projections on the wall, reported by Chodat (1), frequently occur in plants after maturity has been reached, but in small spherical forms are quite rare. These formations are made up of a series of layers of cellulose, and often increase until they are of considerable size (*figs. 23, 24*).

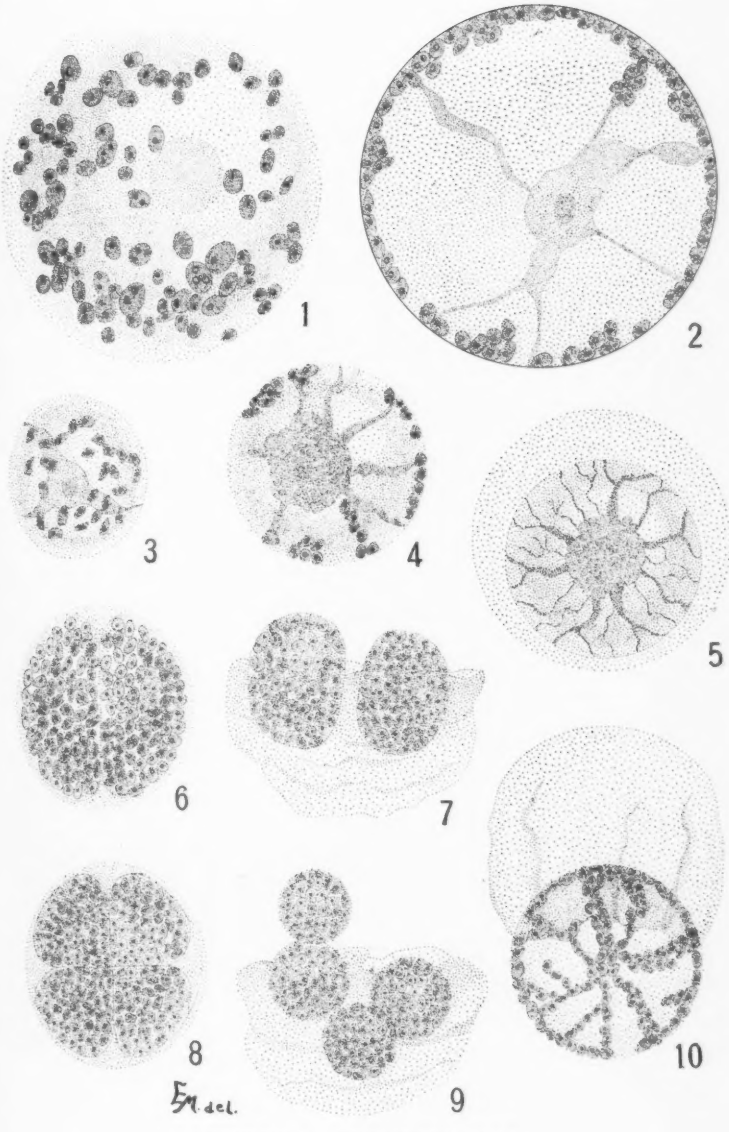
Resting conditions, with a very thick wall and of a reddish color, were found in pure cultures, but the mode of development has not been observed up to the present time. As previously stated, this plant has been cultivated in a pure state for several years, and all the methods resorted to in an effort to bring about

zoospore formation in Eremosphaera were repeated with Excentrosphaera, but without success.

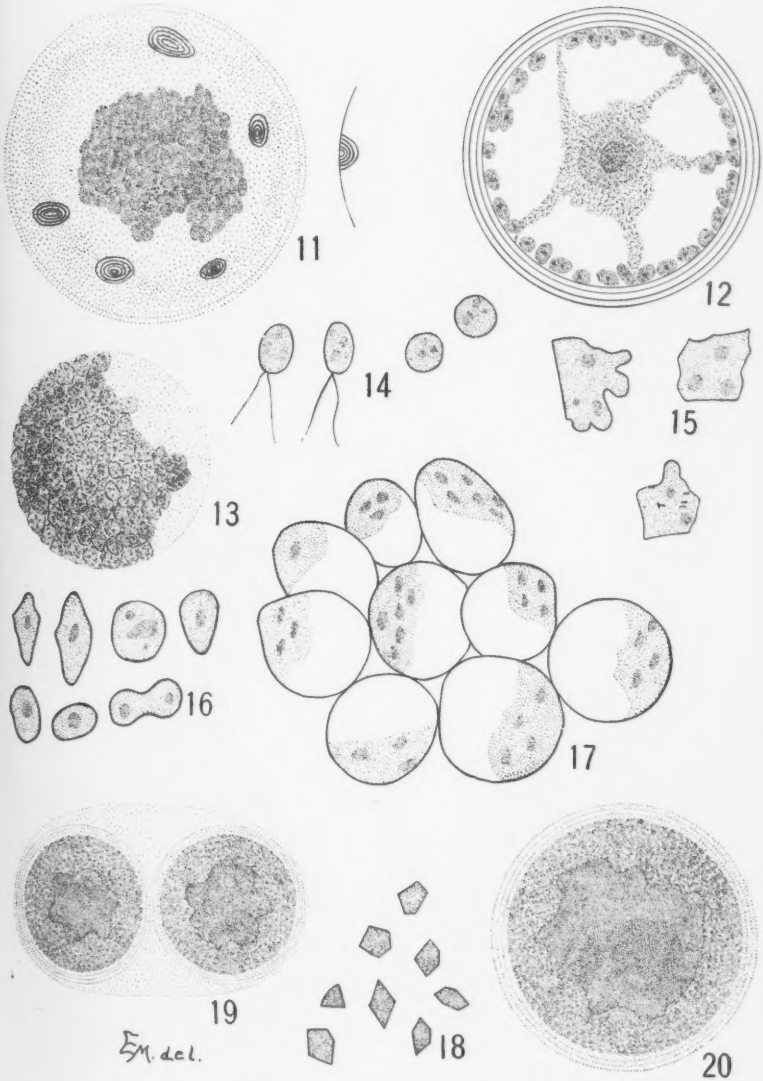
The Eremosphaera material found on Naushon has never shown Excentrosphaera, nor has the Ridge hill material developed it after the original lot was collected. Excentrosphaera has been found in stagnant ponds near Norwich, Vt., which contained, in addition, large amounts of Nitella, Spirogyra, Oedogonium, and related forms. A shallow pool, almost filled with Hydrodictyon, not far from Boston, has also furnished Excentrosphaera in considerable quantities. Neither of these latter localities have ever shown Eremosphaera, although repeated search has been made for it. Unless we are to adopt Borzi's "stadii anamorphici" for all the algae, it does not seem possible that this plant has any genetic connection with any other form. The external resemblance to Centrosphaera, which led Chodat to give that name to it as a supposed stage of Eremosphaera, is certainly striking, but the decided difference in habitat, together with the absence of motile spores and the difference in development, would seem to be sufficient to separate it from that genus. The affinities of Excentrosphaera, so far as known, must be with the Protococcaceae of Wille.

Excentrosphaera, nov. gen.—Plant consisting of a single cell, in mature condition varying in outline from spherical and elliptical to irregular and excentric forms. Chromatophores large, angular, usually radiately arranged, closely lining the wall. Pyrenoids minute, numerous in each chromatophore. Multiplication by means of non-motile spores (aplanospores), which escape by the dissolution of a part of the cell wall. Reaction to all external stimuli negative.

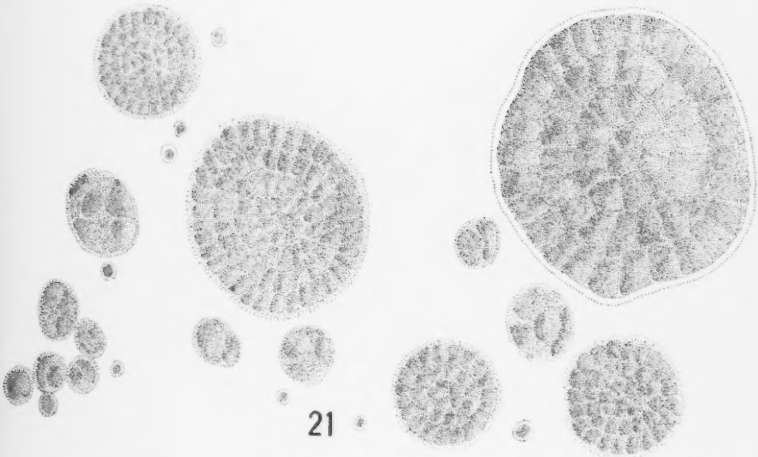
E. viridis, nov. sp.—*Plate XII, figs. 21–27.* Characters of the genus. Plants of bright green color; size of mature cells 22–55μ. Spores 2–3μ. Growing with Eremosphaera, Geneva (?); with Eremosphaera, Micrasterias, Zygnema, etc., Ridge hill, Mass., the year around; in swamps with Nitella and various algae, Norwich, Vt., September–November; with Hydrodictyon in shallow pool, in vicinity of Boston, June–August.

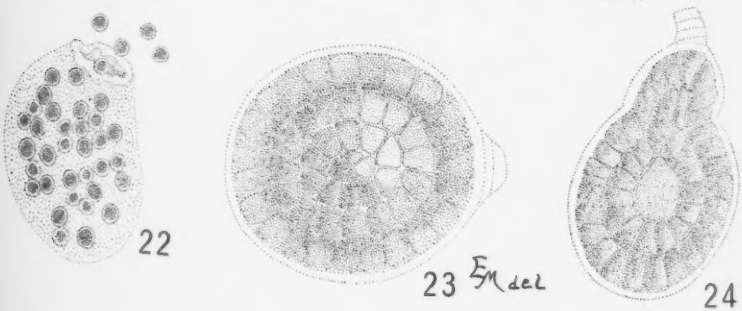


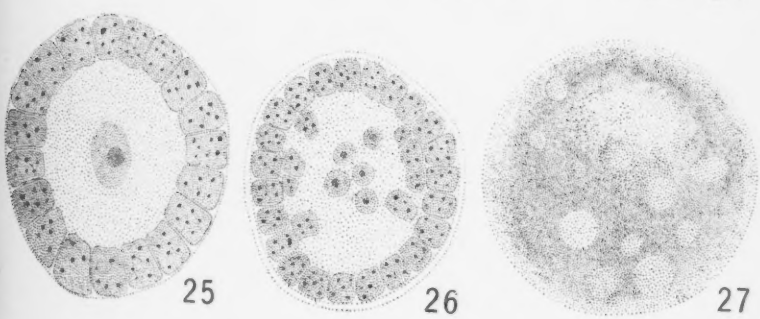
MOORE on EREMOSPHAERA



MOORE on EREMOSPHAERA







MOORE on EXCENTROSPHAERA

This work was commenced in the Cryptogamic Laboratory of Harvard University, and my sincere thanks are due to Dr. Farlow and to Dr. Thaxter for their helpful criticism of the investigation carried on while there.

DARTMOUTH COLLEGE,
Hanover, N. H.

BIBLIOGRAPHY.

1. CHODAT, R., Ueber die Entwickelung der *Eremosphaera viridis* DeBy. Bot. Zeit. 53 : 137–148. 1895.

2. DE BARY, A., Untersuchungen über die Familie der Conjugaten. Leipzig, 1858.

3. DE TONI, J. B., Sylloge Algarum 1 : 616. 1889.

4. DE WILDEMAN, E., Comptes rendus de la Soc. Roy. de Bot. Belge. 1894.

5. HENFREY, A., On Chlorosphaera. Trans. Micr. Soc. Lond. 7 : 25–29. 1859.

6. HOFMEISTER, W. F. B., Ueber die Fortpflanzung der Desmidieen und Diatomeen. Leipzig. 1857.

7. WILLE, N., Die natürlichen Pflanzenfamilien, Algen 1¹ : 58. 1897.

8. WOLLE, F., Freshwater algae of the United States. 1 : 201. 1887.

EXPLANATION OF PLATES.

All the figures are from ink drawings sketched in with an Abbé camera. In the reproduction they are reduced about one fourth. *Figures 14–18* are drawn with a Leitz $\frac{1}{12}$ (oil), oc. 3; all the others with a Leitz $\frac{1}{5}$ oc. 3. The magnifications given are the original ones before reduction and allow for projection.

PLATE X. Eremosphaera viridis De Bary.

FIG. 1. Surface view of large variety (Ridge hill material). × 250.

FIG. 2. Section of same showing nucleus and protoplasmic strands. × 250.

FIG. 3. Surface view of small variety (Naushon material). × 250.

FIG. 4. Surface view showing the retreat of the chromatophores under the influence of strong sunlight. × 250.

FIG. 5. So-called "rejuvenescence." × 250.

FIG. 6. Beginning of the division into two. × 250.

FIG. 7. Division completed and liberation of daughter cells. × 250.

FIG. 8. Division of mother cell into four. × 250.

FIG. 9. Division completed and liberation of daughter cells. × 250.

FIG. 10. Escape of cell from old wall after "rejuvenescence." × 250.

PLATE XI. Eremosphaera viridis De Bary.

FIG. 11. Surface view and section of wartlike formations in wall. × 250.

FIG. 12. Section showing successive formation of walls. × 250.

FIG. 13. Abnormal condition resembling zoosporangium. × 250.

FIG. 14. Foreign organisms found within cell similar to *fig. 13*. × 830.

FIG. 15. Ultimate development of ciliated organisms. × 830.

FIG. 16. Normal appearance of chromatophores, with pyrenoids. ×830.

FIG. 17. Chromatophores after being crushed out in water. × 830.

FIG. 18. Pyrenoids after treating with chloral hydrate. × 830.

FIG. 19. Resting spores formed immediately after division. × 250.

FIG. 20. Resting spore formed from mature plant. × 250.

PLATE XII. Excentrosphaera viridis Moore.

FIG. 21. General appearance with successive stages in development from spore. × 250.

FIG. 22. Escape of spores. × 250.

FIGS. 23, 24. Cellulose projections of wall. × 250.

FIG. 25. Section through cell, stained to show pyrenoids. × 250.

FIG. 26. Section showing first divisions of nucleus previous to spore formation. × 250.

FIG. 27. Homogeneous appearance of cell previous to spore formation. × 250.

DEVELOPMENT OF THE POLLEN IN SOME ASCLEPIADACEAE.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXXII.

T. C. Frye.

(WITH PLATE XIII)

It is well known that in the Cynanchoideae[1] the microspores of each sporangium adhere in a mass, forming what is known as a pollinium. This is true also of some of the Orchidaceae and Leguminosae. Since the three families mentioned are all highly specialized for insect pollination, the adherence of pollen may perhaps be regarded as having no special morphological significance. The Asclepiadaceae are further exceptional in the production of only two sporangia in each stamen. In the Balanophoraceae, Orchidaceae, and Mimosoideae, the number of microsporangia is variable. The large number in some of the Mimosoideae is attributed to the interjection of plates of sterile tissue. In the same way *Lemna minor* is said to form four, the normal number, from a single mass of archesporial tissue.[2] The question arises whether, in the Cynanchoideae, there is any indication of suppression or fusion of sporangia in the earliest stages of their development. More interesting does this become when we recall that in the small group Secamoneae the pollinium in each half anther is paired, but the parts adhere closely.

Little is known about the formation of pollen in the Asclepiadaceae. In the Periplocoideae tetrads are formed, the microspores adhering in groups of four when mature. Of the pollen development in the Cynanchoideae almost nothing is known.

[1] The author follows the classification of Engler and Prantl in *Die natürlichen Pflanzenfamilien.*

[2] Caldwell, O. W., On the life history of *Lemna minor.* Bot. Gaz. **27**: 37–66. 1899.

Chauveaud[3] claims that the pollen mother cells of Cynanchum divide, but mentions only one division, with reduced number of chromosomes, the pollen grains forming from the daughter cells. Here one is left to infer that a mother cell formed only two microspores, or that there was a second division which escaped his observation. Wille[4] examined *Asclepias speciosa*, but was unable to find tetrads. Strasburger[5] finds no tetrad division in *Asclepias Syriaca*. He finds in the anthers what he terms sporogenous cells, radially elongated, large, and rich in contents. These divide by cross walls into two, and the longest, near the middle of the sporangium, into four. He says the resulting cells are homologous with the pollen mother cells of other plants, and develop into microspores without further division. So far as I have been able to learn Zostera[6] and the Cynanchoideae are the only Angiosperms which are reported to form their pollen without tetrad divisions. It was thought that there were no tetrad divisions in the Cyperaceae until Juel[7] found that the nuclear division occurred, but no walls were formed. The reported different pollen formation in Cynanchum and Asclepias, the presence of tetrads in the Periplocoideae, and the small number of cases of pollen formation without tetrad division, all seem to warrant an investigation of the formation of microspores in the Cynanchoideae.

In the spring of 1901 I undertook the task of looking into the pollen formation of some members of the Asclepiadaceae growing abundantly in the vicinity of Chicago. Those examined were *Asclepias Cornuti*, *A. tuberosa*, *A. phytolaccoides*, *A. incarnata*, *A. verticillata*, *Acerates viridiflora*, and *A. longifolia*.

In *A. Cornuti* I was able to trace the development from the

[3] De la reproduction chez les dompte-venin 41. (Diss.) Paris, 1892.

[4] Ueber die Entwickelungsgeschichte der Pollenkörner der Angiospermen 41. 1886.

[5] Ueber das Wachsthum vegetabilischer Zellhäute. Histologische Beiträge 2: 80. 1889.

[6] HOFMEISTER, Bot. Zeit. 10: 121. 1852.

[7] Beiträge zur Kenntniss der Tetradentheilung. III, Die Entwickelung der Pollenkörner bei Carex. Jahrb. f. wiss. Bot. 58: 649. 1900.

archesporium to the pollen mother cell. The first indication of the formation of sporangia is the increase in length of the hypodermal cells on the inner side of the stamen on each side of its median line, thus forming the archesporium (*fig. 1*). While both sporangia are formed from the same continuous layer, they are separate from their beginning; and there are no indications of four. The tapetum on the dorsal side of the sporangium is formed from the third layer of cells—the one next the archesporium. The archesporial cells elongate at right angles to the inner surface of the stamen and divide transversely, resulting in an inner primary sporogenous, and an outer primary wall layer. The beginning of this division is shown in *fig. 1*. By transverse divisions of the primary wall layer there arise four wall layers (*fig. 3*), the inner one or two of which form the tapetum. The tapetal nature of these cells is already evident in their large nuclei and nucleoli, and their deeply staining contents, before they have completed their division (*fig. 4*). In some places the tapetum is composed of one layer, in others of two. Where there are two the outer is often composed of flattened, the inner of isodiametric cells (*figs. 6* and *14*). While the primary wall layer forms its four layers, the plate of cells dorsal to the sporangium also divides and takes on its tapetal character. The primary sporogenous cells contain large vacuoles, while their nuclei are near the middle (*fig. 4*); but even at this stage of development they grade into ordinary vegetative cells at the outer edge of the sporangium, so that it is difficult to determine just where they cease to be sporogenous cells (*fig. 3*). Enough stages were seen in the other species mentioned to warrant the conclusion that the development of the pollen in them is the same in general as in *A. Cornuti*.

From this point the history was most completely followed in *A. tuberosa*. The primary sporogenous cells become the spore mother cells without further division. This is indicated by the nature of the nuclei and by the form and number of the chromosomes. The size of the nucleus increases, and the chromatin collects in granular tangled threads, which together with

the large nucleolus form the staining contents of the large transparent nuclear vacuole—the synapsis stage of the nucleus (*fig.* 7). This stage of the nucleus was also observed in *Asclepias Cornuti*, *A. phytolaccoides*, *A. verticillata*, and *Acerates longifolia*. At the beginning of mitosis the nucleolus often separates into several smaller nucleoli. The chromatin in *A. tuberosa* breaks into five chromosomes which split longitudinally while scattered in the nuclear vacuole (*fig.* 6). They are very small when split, but become much larger as the nuclear wall and the nucleoli disappear (*fig.* 6). After the disappearance of the nucleoli they are short, thick, and much larger than those in the vegetative cells. The number of chromosomes in the spore mother cells is approximately half that in the vegetative cells (compare *fig.* 6 with *figs.* 8 and 9). The exact number in the vegetative cells I was unable to determine. This reduction of chromosomes occurs in the spore mother cells of other plants. The mitotic phenomena attending the division of the cells referred to as spore mother cells closely agree, then, with those in the spore mother cells of other plants, and do not agree with those in the vegetative cells. This is to me conclusive evidence of their spore mother cell nature.

Closely following this division, often before the cross wall is distinguishable, comes the second, with smaller chromosomes, which results in a row of four daughter cells representing a tetrad (*fig.* 10).

Both the rapid succession of these divisions and the formation of four and only four cells from a mother cell homologize well with tetrad formation. Each mother cell divides; those at the pointed upper end of the sporangium slope outward and downward, as shown in *fig.* 5, thus permitting the division of all the cells without great difference in size. The lower end of the sporangium is rounded, and hence the cells there are not greatly modified. These divisions I have no doubt are the ones Strasburger saw in *A. Syriaca*, and this creates a doubt in my mind whether the mother cells near the ends of the sporangia formed only two microspores, as the report would lead one to believe.

This formation of microspores in a row, while not the usual tetrad form, is not peculiar to the Asclepiadaceae. The cells are reported in other arrangements in *Typha latifolia*,[8] *Orchis mascula*,[9] Juncus,[10] and some members of the Periplocoideae.[11]

The cells now become isodiametric, irregular, and crowded. Adjusting themselves to each other they soon lose all indication of their origin as a row of four. The protoplasm becomes filled with short coarse threads which stain readily and obscure the other cytoplasmic structures (*fig. 11*). The walls then thicken very rapidly. This is by the deposition of a layer from within the cells, as is evident later when intercellular spaces appear. When a mature pollinium is cut and squeezed the walls separating the microspores split, and the microspores are squeezed out whole. Where a microspore is in contact with a pollinium wall it separates from it an inner layer (*fig. 16, x*). This suggests that most of the pollinium wall is of a different origin from the walls of the microspores. The nucleus divides after the walls are thickened, forming the generative and tube nuclei (*fig. 13*). The tube nucleus is much the larger and denser. The generative nucleus moves to the side of the cell (*fig. 14*), and is cut off by a wall of considerable thickness (*fig. 15*). The tapetum gradually disintegrates, leaving the pollinium loose in the anther, except for its attachment to the caudicle by its upper end. After the walls begin to thicken the thready protoplasm collects in masses within the cells (*fig. 12*). The masses disappear about the time of the formation of the generative and tube nuclei, and dense fusiform bodies composed of one or more strands, and of unknown nature, make their appearance. In *A. verticillata* they were short, thick, and smaller than in the other species. Their origin may be connected with the thready and dense protoplasm just preceding their appearance. They

[8] SCHAFFNER, J. H., Development of the stamens and carpels of *Typha latifolia*. BOT. GAZ. **24**: 93. 1897.

[9] WILLE, Ueber die Entwickelungsgeschichte der Pollenkörner der Angiospermen 39. 1886.

[10] *Ibid.* 42.

[11] SCHUMANN, Engler and Prantl, Nat. Pflanzenfam. 4^2: 196. 1895.

remained and were seen even in the pollen tubes. The pollen of all the species studied contained them, but they were most abundant in *A. Cornuti*. The tests for calcium oxalate, carbonate, phosphate, and sulfate, and for silicon and starch failed to reveal their nature. They stain like chromatin.

A stage like that in *fig. 16* was frequently found, and seems to indicate the fragmentation of the tube nucleus, although the series about it was not close enough to justify a definite conclusion.

Germination always bursts the pollinium along its outer edge, at the point where the diameter is greatest (*fig. 17*). A cross section shows the pollinium wall to be thinnest there. Germination of the microspores was observed in *A. Cornuti*, *A. tuberosa*, and *A. incarnata*.

SUMMARY.

The development of the sporangia in the Asclepiadaceae studied is the same in general as in other plants, while there are no indications of the phylogenetic history of the reduction in number. The primary sporogenous cells without further division become the pollen mother cells. The latter divide each into four with the usual phenomena accompanying tetrad division, but through mutual adjustment and the close adherence of the microspores the evidences of grouping are lost.

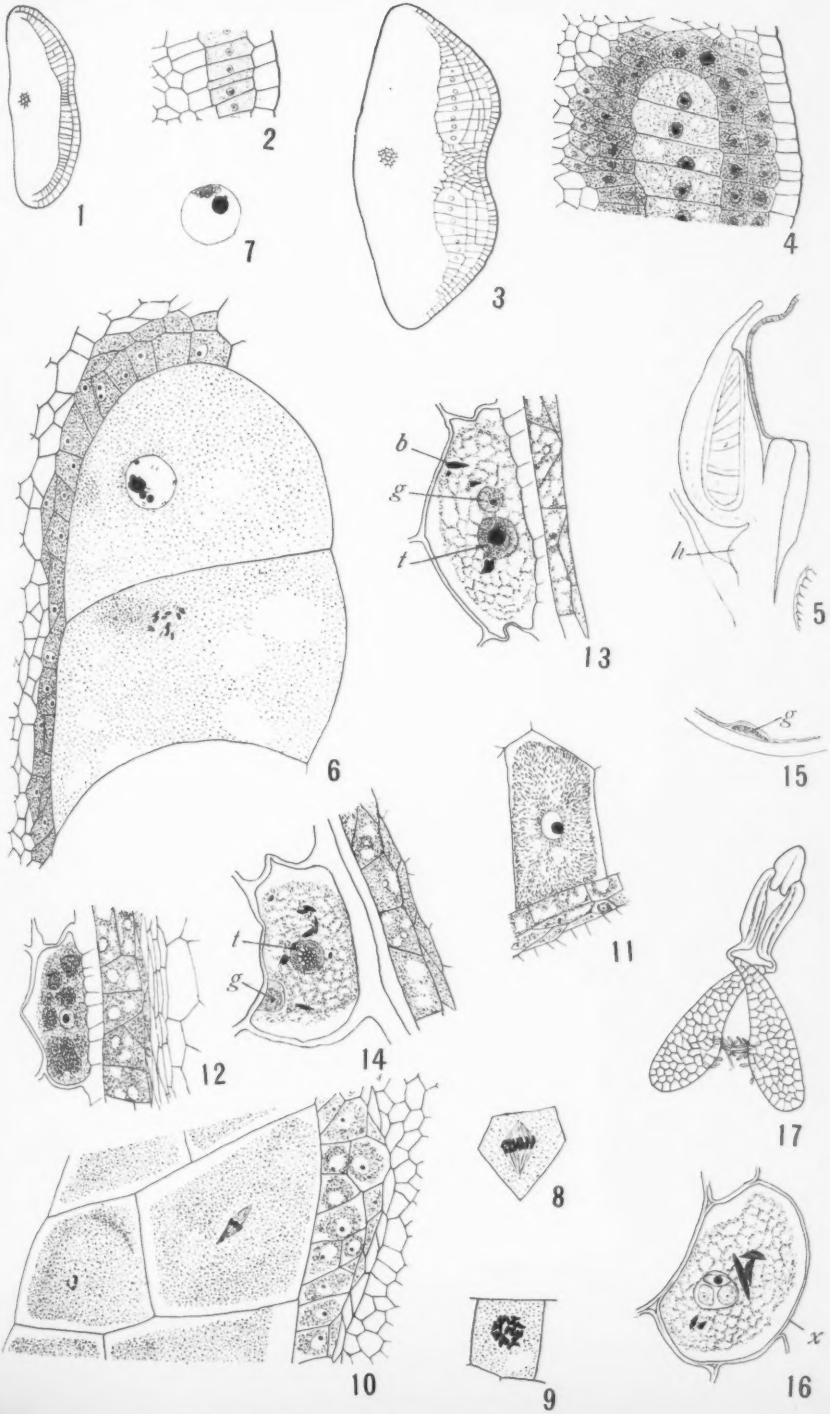
I wish to acknowledge my indebtedness to Dr. John M. Coulter and Dr. Charles J. Chamberlain for their kindly direction and valuable suggestions.

HULL BOTANICAL LABORATORY,
THE UNIVERSITY OF CHICAGO.

NOTE.— Just as this paper goes to press, one by Professor Strasburger, *Einige Bemerkungen zu Pollenbildung bei Asclepias* (Ber. deutsch. bot. Gesells. 19: 450–454. 1901), dealing with *Asclepias Cornuti* and *Cynanchum Vincetoxicum*, has come to hand, confirming in a general way the results reported above.

EXPLANATION OF PLATE XIII.

The figures are reduced to one half their original size. The lenses used were Leitz objectives 3 and 7, and Zeiss $\frac{1}{12}$ oil immersion; oculars, Reichert



FRYE on POLLEN OF ASCLEPIAS

1 and 2, and Zeiss compensating 4, 8, 12, and 18. All drawings were sketched with a Bausch and Lomb camera lucida.

Figs. 1–4. Asclepias Cornuti.

FIG. 1. Cross section of young stamen showing archesporium just beginning the division into primary wall and primary sporogenous layers; somewhat diagrammatic. × 290.

FIG. 2. Part of *fig. 1*, through archesporium. × 800.

FIG. 3. Section across a stamen showing primary sporogenous cells grading into vegetative cells and division of primary wall layer into four layers; partly diagrammatic. × 290.

FIG. 4. Part of *fig. 3*, showing tapetal nature of cells surrounding the primary sporogenous cells. × 800.

Figs. 5–16. Asclepias tuberosa.

FIG. 5. Longitudinal section through stamen showing location of sporangium and orientation of cells within; *h*, hood; partly diagrammatic. × 22.

FIG. 6. Longitudinal section of lower part of sporangium; two spore mother cells undergoing first division; one nucleus in aster stage, the other with chromosomes just split. × 800.

FIG. 7. Synapsis stage of nucleus in spore mother cell. × 800.

FIG. 8. Aster stage in division of a vegetative cell. × 2150.

FIG. 9. Axial view of plate of chromosomes in aster stage in vegetative cell. × 2150.

FIG. 10. Longitudinal section of sporangium near its top showing second division of nucleus of spore mother cell. × 800.

FIG. 11. Section of young microspore showing thready protoplasm; tapetal cells adjacent. × 800.

FIG. 12. Section of microspore containing masses of denser ptotoplasm; walls already thickened; tapetum adjacent. × 800.

FIG. 13. Section of microspore; *b*, deeply staining bodies; *g*, generative nucleus; *t*, tube nucleus.

FIG. 14. Section of microspore showing generative nucleus (*g*) flattened against the wall of the cell and just cut off. × 800.

FIG. 15. Section of a generative cell cut off from the rest of the microspore by a considerable wall. × 900.

FIG. 16. Section of microspore containing what may be a fragmented tube nucleus; *x*, side torn from pollinium wall. × 800.

Fig. 17. Asclepias incarnata.

FIG. 17. Sketch of two pollinia germinating in a 10 per cent. solution of cane sugar; partly diagrammatic. × 45.

ON THE DISTRIBUTION OF RED COLOR IN VEGETATIVE PARTS IN THE NEW ENGLAND FLORA.

F. GRACE SMITH.

THE meaning of red color in the vegetative parts of plants is a subject which very early attracted attention. Beginning with Grew (1677), many observations and experiments have been made, resulting in several theories. Von Mohl[1] (1837) was the first of modern botanists to study the subject with thoroughness, concluding, according to Overton's review of his work, that red color is an incidental result of cooler temperature and intense light. Kuntze[2] (1877), on the other hand, gave an ecological significance to red color, considering it a protection against animals. Stahl[3] (1888) showed that animals usually choose green leaves first, but if hungry eat either green or red leaves. Since this happens in the dark as well as in the light, some difference in the nourishing qualities or in the taste of the red leaves seems to be the determining factor of the choice. Pick[4] (1883), according to Stahl, held the theory that red color favors the breaking up and change of starch into sugar, by absorbing the light rays injurious to this change. Kerner[5] thought the intense light is harmful to the plant, being destructive to young chlorophyll, and that the red color forms a screen, thus permitting the change and passage of food materials. Engelmann[6] (1886) gave no positive meaning to erythrophyll, for it seemed sufficient to him that assimilation takes

[1] Untersuchungen über die winterliche Färbung der Blätter. Included in Vermischte Schriften 375–392.

[2] Schutzmittel der Pflanzen gegen Tiere und Wetterungunst. Gratisbeilage zur Bot. Zeit. Leipzig, 1877.

[3] Pflanzen und Schnecken. Jenaisch Zeitsch. Nat. u. Med. **22**.

[4] Bedeutung des rothen Farbstoffs bei den Phanerogamen und die Beziehung desselben sur Stärkewanderung. Bot. Centralbl. **16**: 281.

[5] Natural History of Plants (transl. by Oliver) **1**: 101–103, 364–366, 483–499.

[6] Die Farben bunten Laubblätter und ihre Bedeutung für die Zerlegung der Kohlensäure im Lichte. Bot. Zeit. **45**: 449.

place, but little retarded by the loss of light. Stahl[7] (1896) agreed with Kerner and Pick in the belief that the red color is a device for promoting the change and passing of food stuffs, not however in its use as a light screen, but by raising the temperature of plant tissues through its property of converting light into heat; cold delays these processes. This warming up of the plant also favors transpiration, an ecological factor as important in Stahl's view as the one mentioned. Overton[8] (1899) presented the theory that the red color is a glucoside compound, produced as a result of sugar concentration in the cell, under the influence of intense light and cool temperature. He assigned no distinct ecological significance to red color and in reality gave us a theory which is a modification of Von Mohl's. MacDougal[9] (1896) has given a good popular account of the theories concerning red color.

Little attention has been given to the study of red color in the eastern United States. Stahl and Overton cite this region with the Alps as offering the best conditions by far for a great display of color. No attempt, so far as I can find, has been made anywhere to study comprehensively the red color in summer foliage, or, in fact, to work up the subject at all in a statistical way, and therefore with a view to seeing how far statistical observations made in New England may agree with the principal theories this study is offered. Thanks are due to Mr. M. L. Fernald, of the Gray Herbarium, for naming many plants, and to Dr. W. F. Ganong, of Smith College, with whose kind assistance and direction the working out of the data was done.

The plants examined were gathered at random in Northampton and vicinity, Springfield, Warren and Woods Hole, Mass., and in Squirrel island, Maine. The proportion of situations, dry and wet, shady and sunny, from which the specimens were taken was about the same. At first only those plants were

[7] Ueber bunte Laubblätter. Ann. Jard. bot. Buit. **13**: 137.

[8] Beobachtungen und Versuche über das Eintreten von rothen Zellsaft bei Pflanzen. Prings. Jahrb. **33**: 171.

[9] Physiology of color in plants. Pop. Sci. Monthly **49**: 1.

noted which showed red color. After most of the data were taken it was realized that the number of specimens lacking red color, but growing in the same situations, was needed for comparison, especially for determining what per cent. of our flora showed red color and what situations produced the greatest proportion of cases. Last summer a record was kept of the number of plants found on Squirrel island, Maine, an island two or three miles in circumference. The total number was 126, of which 102 showed red color; 24 showed *none at that time*, 5 of them being evergreens. Most of these 24 plants were recorded red at other times in other places. These figures, though true for a very limited region, give evidence that red color is more widely prevalent than would be supposed.

The data taken gave the name of the place, situation in which the plant was gathered, whether roadside or woods, whether wet or dry, the amount of shade, height of the plant, part colored, the date, and, as far as was ascertainable by microscopic examination, in what tissues the red color was located. The fact should be emphasized that the date at which the plant was gathered made a decided difference in the color. Owing to the length of the records taken only the results are given here.

In analyzing the results, attempt has been made to think of every possible interpretation of the presence of the color, and to ascertain by percentage how many specimens confirm each.

The first records consider *the part* of the plant in which the red occurs. Of 285 plants showing red, the stem has 211 cases (73.3 per cent.), the petiole 140 (49.1 per cent.), the leaf (mesophyll) 99 (35 per cent. of which 7 per cent. were young leaves), and the veins 66 (23 per cent.). Red color, therefore, is more common in stems than in leaves.

In upright stems more red, or red only, was shown evenly distributed in 138 cases (65.4 per cent.), near the ground in 31 (14.7 per cent.), at the nodes in 23 (10.9 per cent.), at the tip in 3 (1.4 per cent.). Red color, therefore, is not commonly localized, but evenly distributed. Cases where more red was

shown on one side of an upright stem than on another were found to be where light was brighter on the red side.

In creeping stems and inclined branches there was more red on the upper surface in 12 cases (5.7 per cent.), and on the lower surface in one case (1 per cent.).

Of 140 *petioles* more red was shown on the upper surface in 53 cases (38 per cent.), evenly distributed in 46 (32.8 per cent.), near the base in 39 (28 per cent.), on the lower surface in 10 (7.1 per cent.), near the blade in 5 (3.5 per cent.). In petioles, therefore, red color is most frequent on the upper surface, but nearly as often evenly distributed, while some petioles show a tendency to color toward the base.

Of 65 *veins* more red was shown evenly distributed in 32 cases (49.2 per cent.), on the upper surface in 18 (27.7 per cent.), on the lower surface in 15 (23.1 per cent.). It follows, therefore, that in veins, as in stems, the red color is evenly distributed in the majority of cases, and that there is more color on the upper than on the lower surface.

Of 99 *leaves* (mesophyll) more color was shown evenly distributed in 33 cases (33.3 per cent.), on edge in 20 (20.2 per cent.), on upper surface in 18 (18.1 per cent.), at tip (mostly young) in 15 (15.1 per cent.), on lower surface in 14 (14.1 per cent.), at base near petiole in 11 (11.1 per cent.). The conclusions, therefore, are that cases of even distribution are in the majority; that there is more color on the upper than on the lower surface, and on the edge than near the tip.

In a large number of cases the red color was seen on flower stems, bracts, and scales, but because these could not be ascertained for all plants the results were not tabulated. Buds, stipules, spines, tendrils, and a few roots were also found colored red. Out of the 285 specimens 26 were streaked or mottled in some way.

The next records consider the color distribution in relation to external conditions, as light, etc. Of the 285 plants examined 150 (52.6 per cent.) were gathered in dry sunny places, 61 (21.4 per cent.) in dry shady places, 40 (14 per cent.) in wet

sunny places, 34 (12 per cent.) in wet shady places. Dry situations, therefore, result in more color than wet ones; sunny situations in more than those that are shady; dry and sunny have far the most of all; and wet shady the least of all.

Of 211 *stems* 120 (56.8 per cent.) showed red in dry sunny places, 44 (20.8 per cent.) in dry shady places, 31 (14.7 per cent.) in wet sunny places; 16 (7.6 per cent.) in wet shady places.

Of 140 *petioles* 70 (50 per cent.) showed red in dry sunny places, 31 (22.1 per cent.) in dry shady places, 22 (15.8 per cent.) in wet shady places, 17 (12.1 per cent.) in wet sunny places.

Of 65 *veins* 31 (47.7 per cent.) showed red in dry sunny places, 14 (21.5 per cent.) in dry shady places, 12 (18.5 per cent.) in wet sunny places, 8 (12.3 per cent.) in wet shady places.

Of 99 *leaves* (mesophyll) 48 (48.4 per cent.) showed red in dry sunny places, 19 (19.1 per cent.) in dry shady places, 18 (18.1 per cent.) in wet shady places, 14 (14.1 per cent.) in wet sunny places.

The proportion of red in the parts of the plant is about the same for the plant itself; greater number of cases in dry places than in wet; in dry sunny places the largest percentage of all. Dry shady and wet shady places showed about the same number of cases.

An interesting confirmation of these percentages is found in reckoning them theoretically. For example, if 21.4 per cent. of the 285 plants were found growing in dry shady places, out of the 211 specimens showing red on the stem 45 should show it in dry shady places; and 40 did show it.

In dry shady places the numbers expected and attained were as follows: stems 45–44; petioles 30–31; veins 13–14; leaves (mesophyll) 21–19.

In dry sunny places the numbers expected and attained were as follows: stems 111–120; petioles 73–70; veins 33–31; leaves (mesophyll) 52–48.

In wet shady places the numbers expected and attained were as follows: stems 21–16; petioles 17–22; veins 7–8; leaves (mesophyll) 13–18.

In wet sunny places the numbers expected and attained were as follows: stems 33–31; petioles 19–17; veins 8–12; leaves (mesophyll) 13–14.

In sunny places the number of red stems is considerably larger than expected, and in wet shady places the number of red leaves is larger; otherwise the numbers expected and attained are about the same. Percentages might also be worked out for the number of specimens showing red on the stems, near the ground, at joints, etc.

In addition to the 285 plants, records were taken for 234 duplicates growing in the following situations: 129 in dry sunny places, 44 in dry shady places, 35 in wet shady places, 26 in wet sunny places. This accords with the main series except in the exchange of wet shady and wet sunny places.

To determine if the red color present in the spring and summer is a persistence of the early spring coloration, or a new feature, 109 plants were marked in the spring in different localities with copper tags. Plants were marked only when others of the same species near by were red. These were examined in summer and again in the fall, and changes recorded. One hundred plants were recorded the three times, although in some cases the marked specimen was lost and data were taken from neighboring plants of the same kind. In 54 cases red color was lost in some part; in 34 there was no appreciable change; in 28 red color was gained in some part; in 21 it was lost entirely. There was no attempt to tell how many plants without color in spring gained it during the summer or fall.

Of the 54 plants in which the red color was lost there were 36 cases (66.6 per cent.) in the leaf (mesophyll), 13 (24 per cent.) in the petiole, 12 (22.2 per cent.) in the veins, and 11 (20.3 per cent.) in the stem. Color was gained in 14 cases (50 per cent.) in the petiole, in 9 (32.2 per cent.) in the stem, in 6 (22.2 per cent.) in the veins; in 2 (7.1 per cent.) in the leaf (mesophyll).

Therefore, red color cannot be simply a persistence of spring coloration, nor is it simply an addition in the fall, for of 28 cases

of additional color 18 occurred in the summer and 10 in the fall. Color is more often lost in the leaf than in the stem, the cases of its persistence in the leaf through summer and fall being 8, of its loss 36. The percentage of increase in color is greater in stem and petiole than the loss; it is less in the leaf blade; and about the same in the veins. In order to determine in what tissues the red color is present, examination of 207 plants was made with the microscope. The following tables give the results:

		Stem.	Petiole.	Leaf-blade.	Veins.
Epidermis		78	35	41	12
Cortex	Hypodermis	38 } 66	29 } 47	15 } 18	5 } 9
	Collenchyma	28 }	18 }	3 }	4 }
	Parenchyma	65 } 70 } 136	49 } 50 } 97	37 } 37 } 55	16 } 16 } 25
	Sclerenchyma	5 }	1 }	0 }	0 }
Stele	Vasc. bundles	3 } 15	1		
	Pith	12 }			

DRY, SHADY PLACES.

		Stem.	Petiole.	Leaf-blade.	Veins.
Epidermis		9	6	4	0
Cortex	Hypodermis	8 } 11	8 } 10	2 } 2	1 } 1
	Collenchyma	3 }	2 }	0 }	0 }
	Parenchyma	13 } 15 } 26	9 } 9 } 19	9 } 9 } 11	2 } 2 } 3
	Sclerenchyma	2 }	0 }	0 }	0 }
Stele	Vasc. bundles	1 } 6	0		
	Pith	5 }	1		

DRY, SUNNY PLACES.

		Stem.	Petiole.	Leaf-blade.	Veins.
Epidermis		48	18	20	6
Cortex	Hypodermis	18 } 33	9 } 18	8 } 10	3 } 4
	Collenchyma	15 }	9 }	2 }	1 }
	Parenchyma	29 } 29 } 62	19 } 19 } 37	16 } 16 } 26	4 } 4 } 8
	Sclerenchyma	0 }	0 }	0 }	0 }
Stele	Vasc. bundles	1 } 4			
	Pith	3 }			

WET, SUNNY PLACES.

	Stem.	Petiole.	Leaf-blade.	Veins.
Epidermis	15	7	10	6
Cortex: Hypodermis	10	8	3	1
Cortex: Collenchyma	8 (18)	5 (13)	1 (4)	3 (4)
Cortex: Parenchyma	13	9	5	8
Cortex: Sclerenchyma	2 (15) (33)	1 (10) (23)	0 (5) (9)	0 (8) (12)
Stele: Vasc. Bundles	0			
Stele: Pith	2 (2)			

WET, SHADY PLACES.

	Stem.	Petiole.	Leaf-blade.	Veins.
Epidermis	6	4	7	0
Cortex: Hypodermis	2	4	2	0
Cortex: Collenchyma	2 (4)	2 (6)	0 (2)	0
Cortex: Parenchyma	10	12	7	0
Cortex: Sclerenchyma	1 (11) (15)	0 (12) (18)	0 (7) (9)	2 (2)
Stele: Vasc. bundles	1	1		
Stele: Pith	2 (3)			

DISAPPEARANCE OF COLOR IN 54 PLANTS.

	Stem.	Petiole.	Leaf-blade.	Veins.
Epidermis	3	7	22	6
Cortex: Hypodermis	7	5	3	2
Cortex: Collenchyma	(12)	(13)	(21)	(10)
Cortex: Parenchyma	5	8	18	8
Cortex: Sclerenchyma				
Stele: Vasc. bundles				
Stele: Pith	2	0	0	0

In frequency of color epidermis exceeds hypodermis or parenchyma in stem and leaf-blade, but in each case the cortex shows the largest number of cases. In dry sunny places the epidermis has most color, the color gradually disappearing in the stem from the outside in. In dry shady and wet shady places the parenchyma exceeds, in wet sunny places the hypodermis or epidermis. It seems then as if sunlight tends to increase the red color in the epidermis or hypodermis. In cases of disappearance of color, the loss is greatest in the epidermis

of the leaf-blade, and in the cortex of stem and petiole. In 26 cases of loss, the conditions had changed since spring from sunny to shady. This would make it seem as if red might be a protection from intense sunlight, but in 28 cases of appearance of color 13 were found in conditions which had changed from sunny to shady, and 5 were found in conditions which had changed from wet to dry. One might conclude that change of conditions favors change in color, from green to red or red to green, as has been asserted by others.

Most of the plants with red color were gathered in dry sunny places. This does not accord with observations of Stahl, who finds in moist or shady places the most noticeable red coloring. His theory does not seem applicable to the facts just given, for the conditions of sunlight and warmth in this case favor photosynthesis and conduction, also transpiration. The percentage is so large it could not be due to collecting more specimens in the spring or fall, when the temperature is lower, and thus be due to increased sugar concentration according to Overton's theory.

Taking the whole number of cases, the red color gives the largest percentages for stems and petioles, really the conducting parts of the shoot. One might think with Stahl that some advantage is derived from red color in photosynthesis and passage of food material, but again why this is needed in most of these cases is not so clear, since conditions were already sufficiently favorable for transpiration, etc. The large amount of color in the cortex seems to favor Stahl's theory also. If we apply Pick's theory, that the red color protects the conducting parts from the injurious effects of light upon the changing substances in them, we seem to have a strong argument in its favor, for the majority of the cases noted were recorded in dry, sunny places.

In wet shady places only is the percentage of cases of red color in the leaves greater than in the stems and veins. In Stahl's paper most attention is paid to color in leaves, so here is an agreement, if only a slight one, with his theory of the need of warmth to increase transpiration.

In stems, petioles, veins, and leaf-blades the largest percentages are for an even distribution of red color upon the surfaces of these parts. This would seem to show either that the shoot was evenly lighted or that some factor other than sunlight was the determining one in causing red color. However, the upper surfaces of the leaves, veins, and petioles show more color than under surfaces, and this accords with observations of others. Kerner's theory of protection from too great light, and Stahl's of increasing transpiration through the aid of red, apply here, although it is hard to see, as said before, why there is need of greater photosynthesis than is brought about by naturally favorable conditions. Overton's view is not applicable, for cool temperature is certainly not a factor in the conditions. The disappearance of red color in leaves when greater shade is present, and the great number of cases where red is located in the epidermis, are favorable to Kerner's theory of protection.

Another fact agreeing with the latter theory is in the case of upright stems, where one side, the side always toward the sun, shows often the more color. This was noticed continually in Ambrosia.

The red color is intensified at the joints of stems and petioles. This deepening of color, as well as that upon the upper surface of parts, is greatest in proportion in plants growing in wet shady situations. The theory of Stahl applies here, for the passing of food materials may be checked somewhat at the joint, where tubes pass into the stem; but Overton's theory applies just as well, since conduction is delayed here and sugar must be concentrated in the cells of this region. Cool temperature does not appear here however. Any theory of protection from light is not applicable, since the joints are as much shielded as the other parts of the shoot.

A large number of cases were found where the stem was very red near the ground. None of the theories seem to fit this fact.

Cases where color is absent just at the joints and present upon the rest of the stem, where petioles are red near the blade

only, where old tendrils are very red, where color is present in the hairs of leaves and not in the leaf surfaces, are unexplained by any theory; also the appearance of red under the same conditions which usually favor the disappearance of color.

Stahl has given a plausible explanation of color in plants of the moist tropics, where color is located in the cells of tissues near the surface. Overton explains autumnal and spring coloration, but finds, although he can produce color in internal tissues of the plant, he is seldom able to do so in epidermal layers. None of the explanations given apply to all the cases here recorded.

In conclusion it is seen that the statistical observations presented fit no one theory in all particulars. Some facts agree with no theory at all so far as known. The suggestion may be made that with further experimental study red color may be found subserving a number of purposes or having a number of different meanings; or, on the other hand, it may be due to an entirely unknown cause which may fit all cases.

BOTANICAL LABORATORY, SMITH COLLEGE,
Northampton, Mass.

SOME PLANT ABNORMALITIES.[1]

GEORGE HARRISON SHULL.

THE investigation of the abnormal, either in the structure or function of organisms, is often of great value in arriving at correct interpretation of normal conditions. But any specific abnormal form is rare as compared with the frequency of the normal condition, and as no one observer is likely to discover a great number of cases, it is important that all should be recorded.

Already botanists have described very many instances of abnormal plant forms, so that the bibliography of plant teratology is already extensive. Thus Penzig[2] (1894) gives several thousand references to described cases of plant abnormalities.

I. FASCIATION.

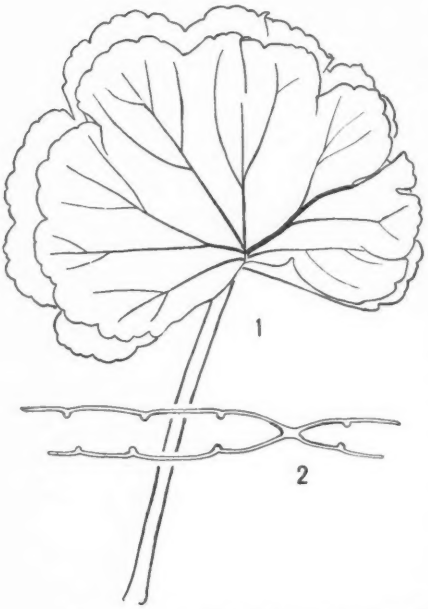
This is a common phenomenon, and so widely distributed that it has been observed by all who have come into any considerable contact with plants. The present cases are described here because of certain interesting attendant characters which may throw some light upon the nature of fasciation.

A remarkable case of fasciation was observed in *Leptilon* (*Erigeron*) *Canadense* L., where a stem had a breadth, in the dried state, of 8.5^{cm}, and the overgrowth at the crest was so great as to throw it into marked undulations. The margins of this stem were apparently normal, as were also the leaves borne on them; and one margin gave rise to a series of normal axillary branches. On the broad sides of the stem, however, the leaves were reduced to a narrowly linear form 0.5–2^{mm} by 2–4^{cm}. This reduction was probably correlated with two other conditions, (1) the great crowding of the leaves, and (2) the greatly increased surface of the stem compared with its volume. It is certain

[1] Contributions from the Biological Laboratory of Antioch College. No. 3.

[2] O. PENZIG, Pflanzen-teratologie. 2 vols. Genoa.

that photosynthesis was carried on chiefly in the tissues of the stem itself, which had an unusually bright green color and delicate texture. No buds were produced in the axils of these reduced leaves until within 6–8^{cm} of the crest, above which point each axil produced a sessile flower bud. The whole side of the stem was covered with numerous fine ridges which, on being traced to their origin, were found to originate in the midribs of the leaves. According to Masters[3] "the striae which these stems almost invariably present exhibit the lines of junction" between the stems by whose union the fasciated stem is formed; but this certainly cannot be true of the striae in this case.



FIGS. 1, 2.—*1*, Leaf of *Pelargonium* sp. with two blades. *2*, Cross section through blades of leaf shown in *fig. 1*, showing the reflection·

In a fasciated stem of *Echium vulgare* L. there was found a greater width near the ground than at a point just below the widening at the crest. Here too the striae are simply the grooves between ridges, which are all plainly traceable to the midribs of the leaves and are undoubtedly the lines beneath which lie the fibrovascular bundles originating in the leaves. By offering a different explanation of these striae the evidence of the union of stems in fasciation is lessened by so much, though not destroyed, since a union may exist without the existence of an evident line of union.

[3] Vegetable Teratology 16. London, 1869.

II. ABNORMAL FOLIAGE LEAVES.

One of the most common abnormalities in Pelargonium is the formation of peltate and funnel-shaped leaves by the growth of leaf tissue where there is normally a sinus. On a specimen which had been observed to produce a number of peltate leaves, there was also found the exceedingly interesting form shown in *figs. 1* and *2*. The petiole was about 1.5 times as broad as a normal petiole and bore two perfectly formed blades. These blades were united from base to margin along a single vein and were placed with the under sides opposed to each other. This leaf gives an excellent illustration of Bateson's[4] (1894) law of reflection, *i. e.*, in the duplication of an organ the arrangement of the parts is the reverse of the arrangement of homologous parts in the normal organ. So perfect was the reflection in this case that the more minute details of outline were reproduced almost as perfectly as in a mirror.

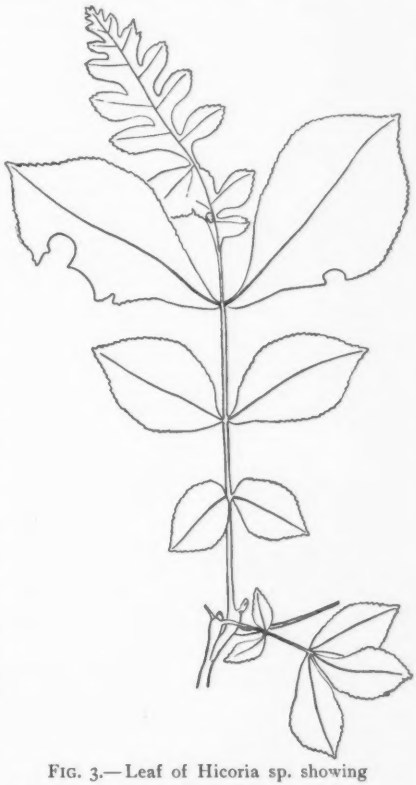


FIG. 3.—Leaf of Hicoria sp. showing a deeply lobed terminal leaflet.

In a leaf of *Hicoria* sp. (*fig. 3*), collected several years ago by the writer, the terminal leaflet was so regularly and deeply lobed as to be almost compound. This modification was decidedly "progressive," although it occurred in the terminal leaflet, where, as

[4] W. BATESON, Material for the study of variation, 474–575. London and New York.

has been so well pointed out by Jackson[5] (1899) the most primitive form is to be expected. There was a small gall just at the base of the leaflet, and as it lay close to the midrib and partially deranged its tissues, the peculiar form of this leaflet may have been due to a pathological condition.

III. ABNORMAL FLORAL ORGANS.

In the summer of 1900 a small plot of *Lathyrus odoratus* L. was found to be producing a considerable number of abnormal flowers. A few of these were dissected and the parts carefully drawn at the time (*figs. 4–30*). The inflorescence of this species usually has only three flowers, but occasionally varies from two to four. *Fig. 4* represents a double inflorescence in which a two-flowered inflorescence has apparently arisen, axillary to the lower flower of a four-flowered inflorescence. Abnormal floral organs were numerous and interesting. I have shown the parts and arrangement of the normal flower in *figs. 5–7*. The combination of abnormalities in each flower can best be exhibited by description of the cases examined. In each case the floral organs not mentioned were normal.

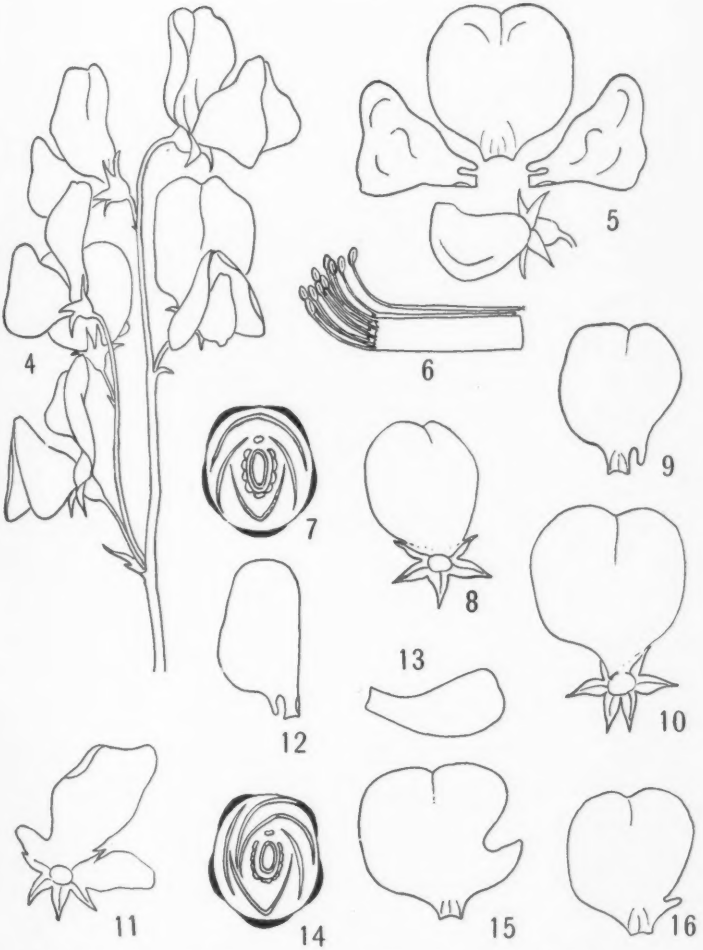
Case 1. An outgrowth from the margin of the sinus between the upper calyx teeth assumed the form and coloring of the vexillum. Vexilla two. (*Fig. 8.*)

Case 2. Calyx with a petaloid outgrowth from the upper sinus. This outgrowth had a lanceolate form instead of the nearly orbicular form of the vexillum. Vexilla two. Stamens eleven, all united.

Case 3. The upper edge of an upper calyx lobe dilated slightly and colored. Vexilla two, the outer having a downward hook like that of an ala, and somewhat narrower than normal. Stamens eleven, two nearly free at the base but united to the other nine above. (*Fig. 9.*)

Case 4. Calyx the same as in *1*. Vexilla two. Stamens twelve, all united to form a tube.

[5] R. T. JACKSON, Localized stages of development in plants and animals. Mem. Boston Soc. Nat. Hist. **5**: 89–153. *pls. 16–25.*



FIGS. 4–16.—Abnormal floral organs in *Lathyrus odoratus*. For details see text.

Case 5. Calyx normal in form but with a touch of color between the upper teeth. Vexilla two, the inner one having one margin enclosed within the carina.

Case 6. Calyx with six teeth, and with a large expansion between the upper ones. One margin of this expansion was free and inserted within the calyx like a vexillum. This structure was probably a union of a vexillum with a petaloid outgrowth of the calyx, although no line of junction was apparent. Free vexillum none. Stamens ten, united into a split tube. (*Fig. 10.*)

Case 7. Calyx as in *1*. Vexilla two, one with a downward hook. Stamens eleven, united into a tube.

Case 8. Calyx as in *1*. Rest of flower normal.

Case 9. The tissue of two of the upper sinuses of the calyx was expanded into irregular petaloid bodies, the upper one with a divergent lateral lobe. Vexilla two, each having the form of half a normal vexillum, one with a prominent downward hook. Alae abnormally narrow, curved upward and outward, and lacking the usual overlapping edge. Stamens twelve, of which eleven were completely united, the twelfth partially adherent. (*Figs. 11–13.*)

Case 10. Calyx with a slight petaloid expansion which was united edge to edge with the outer vexillum. Vexilla two, each having one margin enclosed in the carina. One ala external. (*Fig. 14.*)

Case 11. Calyx the same as in *1*. Vexilla two. One ala narrow and much curved upward. Stamens nine united, one free, and one nearly free.

Case 12. Calyx with six teeth. Vexilla two, each with a lateral lobe, one lobe unusually large. (*Fig. 15.*)

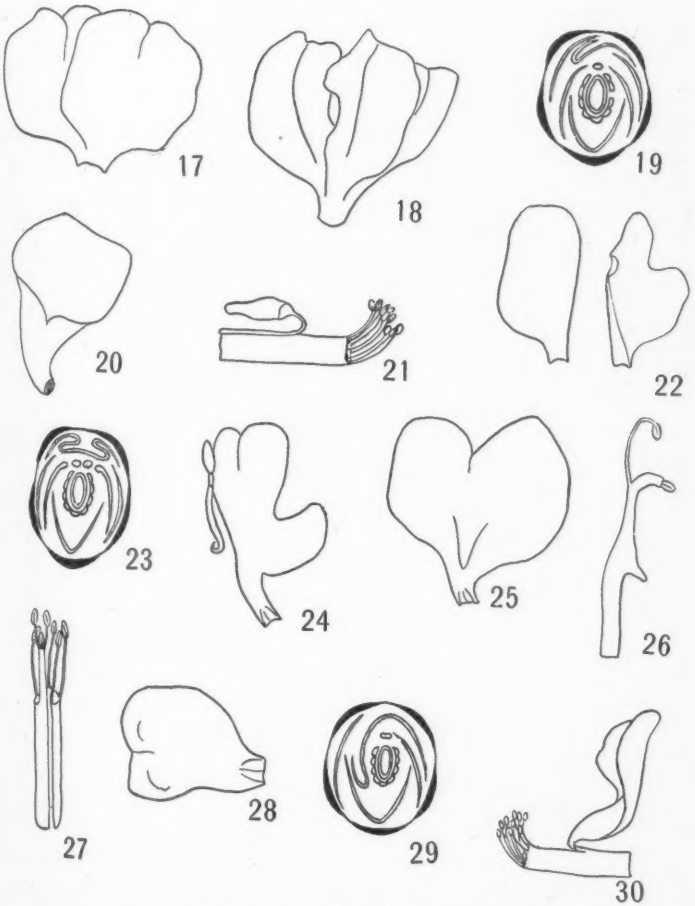
Case 13. Calyx teeth six, the lower two narrower and more approximate than the others. Vexilla two. Stamens nine united, three free.

Case 14. Vexilla two. Stamens nine united, and two free.

Case 15. Vexilla two, each with a lateral basal lobe on the upper side. (*Fig. 16.*)

Cases 16 and *17.* Vexilla two, the second having one margin enclosed in the carina. Stamens ten united, one free.

Case 18. Vexilla two, which were slightly united edge to edge at the base. Stamens diadelphous, two and nine. (*Fig. 17.*)



FIGS. 17–30.—Abnormal floral organs in *Lathyrus odoratus*. For details see text.

Case 19. Vexilla three, all alike and nearly normal in form.

Case 20. Vexilla three, all united. Stamens nine united, three free. (*Fig. 18.*)

Case 21. Vexilla three, the middle one with one side folded

back upon itself. Stamens triadelphous, one, two, and seven. (*Fig. 19.*)

Case 22. Vexillum with margins turned backward and coalesced, forming a funnel which was adherent to the calyx tube at the base. Stamens two free, nine normally united, with a twelfth united for two-thirds of its length. This filament was slightly enlarged and colored, and had its anther converted into a body of the same color and texture as the petals. (*Figs. 20, 21.*)

Case 23. Vexilla two, the second shaped like half the first and balanced on the other side by a petaloid stamen having a yellow spot, corresponding to an anther, on the inner margin. Other stamens normal, nine united and one free, the free stamen arising between the two petaloid bodies within the normal vexillum. (*Fig. 22.*)

Case 24. Vexillum doubled upon itself on both sides. Alae two on each side, the supernumerary alae having the hooks on the lower side, *i. e.*, toward the normal alae, in this respect appearing as a reflection of them. One of these supernumerary alae occupied the position of a free stamen. Stamens nine united, two free. (*Fig. 23.*)

Case 25. Vexilla two, the first notched to one side of the center, the second with a large lateral lobe, and having one margin enclosed in the carina. The enclosed margin of the second vexillum bore a small appendage which was nearly spiral below and ended above in an erect wing. This appendage was probably the homologue of an anther. (*Fig. 24.*)

Case 26. Vexilla two, the outer joined below, margin to margin, with one ala.

Case 27. One ala joined to the first vexillum, this double petal external. Second vexillum of normal form, but with one margin included in the carina. Upper stamen free (as normal), beside it a broad filament with a lateral overlapping hook and colored like a petal. This broad filament was topped with an anther and had a normal filament branching from it at a point two-thirds of its length from the base. The remaining stamens were united into a split tube bearing upon its outer margin four

normal filaments, and one broader filament formed by the union of three filaments. This bore at its summit one sessile anther, and at each side of this sessile anther a short-stalked one. (*Figs. 25–27.*)

Case 28. One ala external and lacking the usual hook. One side of the vexillum folded back and included in the carina. (*Figs. 28, 29.*)

Case 29. Nine stamens united, the tenth united to the other nine for half the length of the tube, then spreading back with the form and coloring of a second vexillum. (*Fig. 30.*)

These abnormalities may be summarized as follows:

1. Abnormalities of the calyx. (*a*) In two cases there were found six calyx teeth, and (*b*) in eleven cases a petaloid inflation grew from the sinus between the upper teeth. This petaloid outgrowth varied from a small colored area in a normally formed sinus to an expanse of tissue having the size, form, and color of a perfect vexillum.

2. Abnormalities of the vexillum. (*a*) In twenty instances there were two vexilla, and in three cases three vexilla were found. In about half, the second vexillum was normal in form, the variations from this being in two directions, (i) toward the wing with its downward hook on the one hand, and (ii) toward the stamen on the other. (*b*) In two cases there was a union between an ala and the outer vexillum. (*c*) Union of the vexilla was found in two instances.

3. Abnormalities of the alae. (*a*) In two flowers the alae were unusually narrow and curved upward. (*b*) In two cases, as mentioned above, there was a union between an ala and a vexillum. (*c*) In one case there were two alae on each side.

4. Abnormalities of the stamens. (*a*) An approach to the form and coloring of the petals. Almost every degree of petalody was found from a petaloid appendage or a broadened filament with a hook, to the form of half a vexillum. (*b*) Three flowers had two free stamens, and two had three free stamens. (*c*) Thirteen had an unusual number of united stamens, mostly ten or eleven, in two instances reaching twelve. (*d*) In several

the stamens were triadelphous, one, two, and nine, or one, two, and seven.

5. Abnormal aestivation. (*a*) In three cases one ala was external to the vexillum. (*b*) In six instances the supernumerary vexillum had one margin enclosed within the carina. (*c*) In several cases there was an abnormal folding of the vexillum upon itself.

There have been but few cases recorded of the union of sepals in *Clematis*, and belonging as it does to a family which typically has all the parts distinct, the union of parts is all the more remarkable. Perhaps the most noteworthy case of this kind is that described by Jaeger[6] (1828), in which the sepals of *Clematis Viticella* L. were united into a bilabiate tubular perianth. Ch. Fermond[7] (1884) has found many cases of three-parted perianths in *Clematis* sp., and Cockerell[8] (1897) remarks upon the common occurrence of the union of two sepals in *C. ligusticifolia*. In a specimen of Clematis growing at Edgewood, North Hampton, O., said to be a seedling of *C. Jackmani* of the gardeners, there are found every year many cases of similar union of sepals, and in varying degrees of union, from the slight union of two sepals to the complete union of all the sepals into a regular, tubular, gamosepalous flower (*figs. 31–34*). This complete union, shown in *fig. 34*, does not occur often, but I have found two like the one figured. If this is a seedling of *C. Jackmani*, its variations are rather remarkable because of the almost absolute invariability of that form. In the "Star of India"[9] Clematis there is a marked tendency to depart from the typical four-parted perianth, and to produce flowers having six sepals. In this species are found many cases of division or of union of sepals.

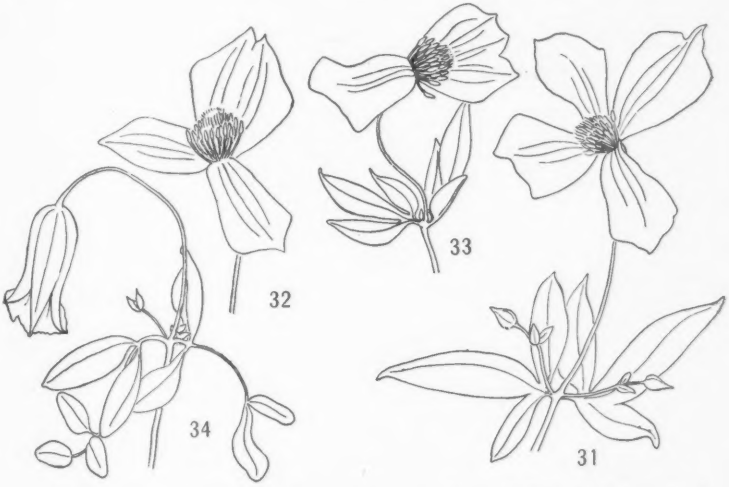
[6] Nov. Act. Acad. Caes. Leop. **1828**: 641. *pl. 37*.

[7] Essai de phytomorphie, ou étude des causes qui déterminent les principales formes végétales. 2 vols. Paris.

[8] Bot. Gaz. **24**: 293.

[9] This is the garden name. I have been unable to determine its specific relationship.

Two of the most striking cases of abnormality in Clematis are shown in *figs. 35* and *36*, although similar cases have been frequently described, indicating that the displacement and coloring of the leaves which are nearest the flowers is a common abnormality in the genus. The two figured were both collected from the same plant of the "Star of India" Clematis, although several seasons intervened between them. In *fig. 35* there



FIGS. 31–34.—Abnormal floral organs in a seedling of *Clematis Jackmani* (of gardeners); *31*, normal flower; *32*, two sepals united; *33*, three sepals united; *34*, all the sepals united into a gamosepalous perianth.

appears what at first seemed to be a reversion of the greater part of a sepal to an ordinary foliage leaf; the remainder retained the form, delicate texture, and rich coloring characteristic of the sepals. On the examination of the normal inflorescence, however, it appears that this organ, instead of being a partly reverted sepal, in reality is the result of a coalescence of a sepal and a leaf from the node next below the flower. The chief evidences of this are found in the absence of one of the leaves from that node, and the presence of a marked decurrent line extending from the leafy organ down the side of the peduncle to the node.

FIGS. 35, 36.—Abnormal floral organs in "Star of India" Clematis (of gardeners); *35*, union of leaf and sepal; *36*, union of peduncle and petiole, one leaf with leaflets partly colored (*pg*), and one leaf entirely changed to a sepaloid body (*pg'*).

The bud which is normally axillary to the removed leaf failed to develop.

Fig. 36 is a somewhat similar case, but more complicated. Here, too, there is an adnation of the petiole of the leaf to the peduncle, and two of the three leaflets are partly colored like sepals. From the groove at the side of the coalesced petiole and peduncle arises an axillary branch. This branch bears, at the next node above, a leaf which in every respect resembles a sepal, and which failed to produce a bud in its axil.

All the cases here described and figured are in the herbarium of the writer, except those of Lathyrus which were dissected, and the parts sketched and described from the fresh material.

YELLOW SPRINGS, O.

BRIEFER ARTICLES.

MEISSNER ON EVERGREEN NEEDLES.

(WITH ONE FIGURE)

A RECENT double number of the *Botanische Zeitung*[1] is devoted to a third treatise by Meissner on evergreen needles. This time the theme is chiefly the relation of the length of stem and needle, in support of his previous attack on the idea advanced by Kraus,[2] and supported by myself,[3] that the thrifty growth of stem and leaf may be expected to occur together. Part I of Meissner's paper contains in tabulated form numerous measurements of stems and needles of Pinus, Abies, and Picea. In a large part of these the variations in needle length are without any apparent relation to that of the stem. Negative testimony of this kind is not very strong, for a more judicious than judicial selection of material can make it show almost anything. For instance, Meissner (p. 30 *et seq.*) would prove by it that I am unreasonable in expecting the different parts of one tree to vary alike in the growth of stems and needles.[4] While it must be said that the frequency of exceptions has surprised me, it has still seemed to me in the observation and measurement of conifers, wild and cultivated, in various parts of the United States, that in a great majority of instances the stems and needles vary in length together. But perhaps Meissner would have drawn the opposite conclusion in the same forests, with an equal desire to see things as they are. Results obtained by the statistical method can hardly ever have the weight of those yielded by judicious experimentation.

Part II deals with mutilation experiments. As would be expected, if the mutilation compels the tree to devote its plastic material to the

[1] Ueber das Verhältniss von Stamm- und Nadellänge bei einigen Coniferen. Bot. Zeit. **59**: 25. 1901.

[2] Abhandl. d. naturf. Gesells. zu Halle **16**: 363. 1886.

[3] A biological note on the size of evergreen needles. Bot. Gaz. **25**: 427. 1898

[4] The proportionate length of stem and needle on the main axis and its branches *in one season* is an altogether different subject.

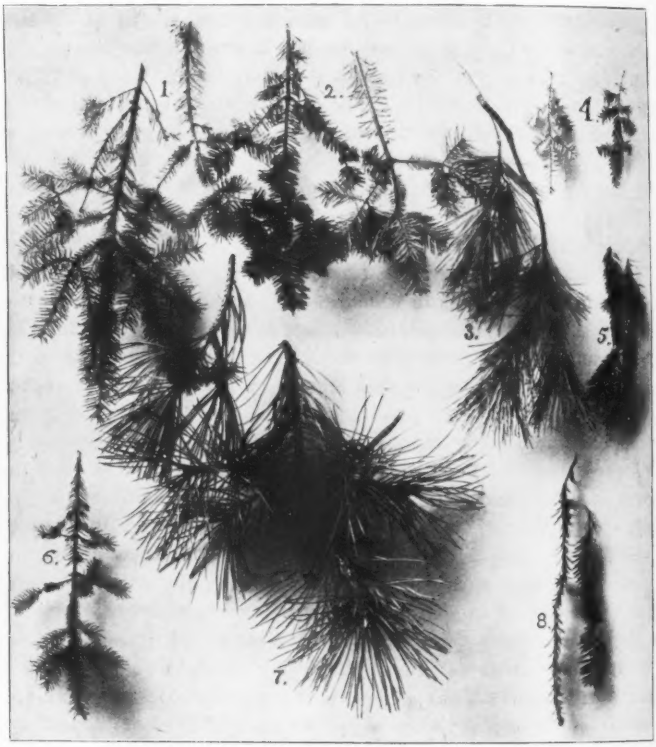
development of a few members, their growth will be stimulated: while robbing it of plastic material or the chance to form, it results in a stunted growth.

Part III, on the annual period of growth of stems and leaves, is the most valuable part of the paper. Meissner shows by measurements that the chief growths in length of stems and needles fall at different times. In Pinus the stem almost finishes its season's elongation, while the needles remain relatively short, the relations in Abies and Picea being just the reverse of this. The dry weights of stems and needles at various times during the months of growth vary in general with the lengths. A moment's reflection will satisfy anybody who has seen evergreens grow that Meissner is correct. Transitory unfavorable conditions early in the season will therefore tend to hinder the growth of the stem of Pinus more than that of the leaves. The maximum growths of stems and needles at different times is a physiological explanation of the cases in which short year's-stems bear long needles, or *vice versa*. But while this makes exceptions intelligible, I am by no means ready to agree that there is no connection between the sizes of stems and needles, or that Kraus and I were wrong in expecting both to vary, in nature, with the general condition of the plant. Neither of us could have thought of maintaining that leaves and stems could never vary independently; that external factors, such as light, must directly influence both alike. Trees do not respond at once to changes in the weather to such an extent that they will often be stunted in May and thrive in June, or grow luxuriantly in May and then abruptly halt. At least my observations on the whole resultant growth indicate that they do not.

The influence of bad conditions on the stages of growth previous to active enlargement has been left largely out of account, and may appropriately receive a word here in the light of Meissner's results. In my paper the area of cross sections of the needles was given, and was always least the season following transplanting. The difference was due to the size of the cells, the number not being materially different from that of other years. Thus in leaves of *Pinus Austriaca* (cf. *loc. cit.* p. 433) the number of cells in cross section was as follows:

	1895	1896	1897
Epidermis	176	176	246
Outer parenchyma layer	77	76	96
Endodermis	39	38	48

The number of cells was surprisingly the same in 1895 and 1896, though the difference in size was very great. The leaves of 1897 were exceptionally thrifty in all respects. The larger leaves contained more resin ducts. This plant was transplanted rather late, when the leaves



CONCOMITANT DWARFING OF STEMS AND LEAVES OF CONIFERS.

1. Picea alba; 2. Abies balsamea; 3. Pinus Strobus; 4. Tsuga Canadensis; 5. Picea pungens; 6. Picea nigra; 7. Pinus Austriaca; 8. Taxus baccata.

of deciduous trees were beginning to grow, probably about the first of April. The exact date is not known, and is not important because it would indicate a definite stage in development only for the one year and locality. The fact that the trees did not have their growth checked

before the first phase of the season's growth is indicated not only by the full number of cells, but also by the presence usually of at least the normal number of needles (*loc. cit.* p. 429).

There are a number of trees of *Picea excelsa* on the campus of West Virginia University that were transplanted in 1899, several weeks earlier in the season than the Bloomington trees. While the size of the cells is not nearly proportional to that of the needles, the number formed during the spring following transplanting falls somewhat behind. The numbers in an average case are as follows:

	1898	1899	1900
Epidermis	122	114	140
Outer parenchyma layer	91	80	106
Endodermis	22	18	25

The whole question of the growth of the needle will reward more experimental study, and Meissner's interesting paper should stimulate it.

The accompanying photograph is of the plants described by me in 1898, and will show the concomitant dwarfing of stems and needles better perhaps than tables of measurements did.— EDWIN BINGHAM COPELAND, *Monroe, Wis.*

THE INSTABILITY OF THE ROCHESTER NOMENCLATURE.

SINCE the publication of my article in the BOTANICAL GAZETTE for last March[1] three communications have appeared which discuss certain details there presented. Two of these letters, from Mr. C. L. Pollard[2] and from Professor L. M. Underwood,[3] question the significance of facts presented by me in parallel columns; while a third letter, from Professor N. L. Britton,[4] presents at more length than was done by me the practical reasons why the first species of a complex genus should not necessarily be treated as the type. These articles bearing directly upon the vital question of stability in botanical nomenclature must leave the general reader in some doubt as to the exact force of certain arguments I have already discussed. It may not be out of place, therefore, to ask for a brief consideration of the points thus newly emphasized.

[1] BOT. GAZ. 31: 183. 1901.
[2] *Ibid.* 31: 285. 1901.
[3] *Ibid.* 31: 365. 1901.
[4] Science 13: 588. 1901.

Mr. Pollard quotes from my article certain sentences embodying conclusions which he characterizes as misleading. The conclusions thus referred to were to the effect that in 1900 Professor Underwood, following logically and consistently the Rochester Code, used 25 per cent. of names different from those used by him in 1896, when he likewise asserted that he was following the Rochester Code. Mr. Pollard's contention is that this fact does not afford a proper basis for criticism of the Rochester Code, because most of the changes made by Professor Underwood represent very recent segregations among the ferns, comparable with the divisions made within three years in the genus Antennaria. Yet it does not seem to have occurred to Mr. Pollard that, in omitting the footnote to the paragraph quoted, he is possibly misleading that large body of readers who habitually neglect to verify quotations and references. Had he carefully read and quoted the two sentences as they were originally published with the footnote: "The true ferns alone are here considered, and the genus *Botrychium* is purposely omitted, since that genus has been subdivided by Professor Underwood to such an extent that comparative figures would have little definite significance," he would have found it unnecessary to inquire whether I do not "recognize the necessity for occasional segregations." Every working systematist must recognize such necessity; but the segregation of perplexing polymorphous types is a very different thing from the raking up of older and more or less obscure appellations for plants the names of which have long been established. The latter is a nomenclatorial matter, the former botanical; and if anyone has read into my previous remarks the least opposition to such division of confused groups as shall lead to a clearer understanding of the forms, he has found that which I in no way intended.

But most of the ferns under discussion cannot be placed by Mr. Pollard under the same category as the recent segregates of Antennaria (and likewise Botrychium), for *they do not represent new points of view unknown in 1896*. Matteuccia is a name given in 1866 to Willdenow's Struthiopteris, which was segregated in 1809 from Osmunda; our Dennstaedtia was separated from Dicksonia in 1857; Filix was published by Adanson in his well known *Famille des Plantes* in 1763; Phyllitis was re-distinguished in 1844; and it is certainly not a new idea to treat species of the complex genus Aspidium under the name *Polystichum*. Neither are *Phegopteris Robertiana* and *Notholaena dealbata* now treated as species for the first time. The former was published

by Hoffmann in 1795 as *Polypodium Robertianum*, the latter by Pursh in 1814 as *Cheilanthes dealbata*. In 1896 Professor Underwood had already published five editions of a work on North American ferns, and he was consequently in a position to know of the earlier conceptions and treatments of these plants. At that time he was publishing according to his interpretation of the Rochester Code, and the names thus published, we were assured, were those which would stand. Yet after having established (as he supposed) these names according to strict priority principles he has found occasion to alter 25 per cent. of them. Has his application of the Rochester Code brought uniformity?

In his "Open Letter" Professor Underwood shows very conclusively that "when its bald statements are unqualified," "the deadly parallel" "seems to mean more than the facts will warrant." For, avowedly with the purpose of showing that "the personal preference hit-or-miss system of Kew and Berlin" is bringing us unwarranted confusion in plant names, he places in parallel columns twenty-one fern names which appeared in the *first* edition of Gray's *Manual* and the twenty-one more or less dissimilar names for the same plants in the *sixth* edition. By the thoughtless reader, with "its bald statements . . . . unqualified," this comparison might seem completely to dispose of my criticism of the recent changes of names made by Professor Underwood. Yet it should be borne in mind that such comparisons may "mean more than the facts will warrant." Professor Underwood implies that the application of the combined Berlin and Kew rules is responsible for the changes between the first and the sixth editions of the *Manual*. Can it be that he "forgot" that the *first* edition was issued in 1848, the *fifth* edition (Pteridophyta by D. C. Eaton) in May, 1867, and the *sixth* edition in 1889, *all before the Berlin rules were formulated in 1897?*

It was three months after the fifth edition of the *Manual* went to press that the Paris convention of 1867 was held and the DeCandollean Code was drawn up. Consequently the sixth edition (1889), by Watson and Coulter, was the only one published after the adoption of the Paris Code of 1867. Furthermore, since even this edition was published eight years before the rules of the Berlin botanists, a comparison of the first edition (1848) and this sixth edition (1889) is no very logical proof that the Berlin rule of 1897 is "unseaworthy."

The fact is, that the names in no edition of Gray's *Manual* have been based on the combination of the Berlin rule for genera and the so-called Kew rule for species, which was recently advocated by me.

This simple and definite method of obtaining a uniform system of names has been carefully tested, however, during the past half decade, and it has appealed as practical to many besides the "trans-Carlines."

Let us now consider, on the other hand, the points raised by Professor Britton. The first rule of the Rochester Code reads: "Priority of publication is to be regarded as the fundamental principle of botanical nomenclature." The fifth rule that "*Publication of a genus consists* only (1) in the distribution of a printed description of the genus named; (2) *in the publication of the name of the genus and the citation of one* or more *previously published species* as examples or types of the genus, with or without a diagnosis" [italics ours]. A recommendation adopted by the reformers at Madison reads: "In determining the name of a genus or species to which two or more names have been given by an author in the same volume or on the same page of a volume precedence shall decide."

By Professor Underwood, as already emphasized in the March GAZETTE, this principle of strict priority has been applied in the determination of the type of a complex genus. Professor E. L. Greene, likewise, has made important changes based upon its rigid enforcement. Professor Britton, too, has more than once maintained that priority of place (precedence) is final, saying, in regard to the now famous case of Buda and Tissa: "I accepted *Tissa* rather than *Buda* for the simple reason that it *stands first on the page* in Adanson's 'Familles.' *That is priority, I am sure*" [italics ours].[5] He has further said that this principle (priority of position) will be accepted by those "who have recognized the necessity of adopting methods of procedure which will render the system of nomenclature stable."[6] And again, "the number of cases in which change is desirable by reason of priority of place is not great."[7] Thus, in 1890, Professor Britton clearly defined what he meant by priority. In 1892, "after a very careful consideration," the Rochester Code was formulated; and in 1893, after plenty of time for further deliberation on its fundamental principle, the code was augmented by the recommendation above quoted.

Priority has been talked of until the subject has become a tedious one; and that it is the ruling principle of the reformers has been so often avowed as to become axiomatic. It is not surprising, then, to find, in the *Illustrated Flora* in 1896, the statement that "its [priority's]

[5] Jour. Bot. **28**: 295. 1890.

[6] Jour. Bot. **28**: 371. 1890.

[7] Jour. Bot. **28**: 372. 1890.

adoption is the only practicable way of securing stability to the original names." This idea has permeated the writings of the reformers, and they have over and over again asserted in books and papers for amateurs and "the younger generation" that the names they advocate are alone the ones which can stand.

That the principle of strict priority (the fundamental law of the Rochester Code) has been many times ignored by those who claim to follow it was sufficiently emphasized in the March GAZETTE. Indeed, when Professor Greene pointed out,[8] in 1896, that the principle of priority demanded that the first species of a complex genus be taken as the type, he was merely showing the logical outcome of the principle. When again, in 1899, Professor Underwood followed the same interpretation in his *Review of the Genera of Ferns*,[9] he was merely following conscientiously the fundamental principle of the Rochester Code, and the law so often vigorously defended by Professor Britton, who "accepted Tissa rather than Buda for the simple reason that it stands first on the page in Adanson's 'Familles,'" saying, "That is priority, I am sure."

After such clear definition of the principle of priority by Professors Britton, Greene, and Underwood, we are now amazed to see from Professor Britton's pen a convincing argument against the uniform selection of the first species as the type of a complex genus. Where shall we look for that long-promised "uniformity" when, in writing of the principle as logically followed by Professor Underwood and more than once by Professor Greene and by Mr. Thomas Howell, Professor Britton now says, "Inasmuch as a great many genera have at their first publication been made to include more than one species, and in a large number of instances some of these, often the first in position, have been used by subsequent authors as the types of additional genera, this latter-day proposition affects an enormously greater number of cases than those which fall properly under the operation of the rule"?[10] And when, continuing his argument against the necessary acceptance of the first species as the generic type, he says "*it is, therefore, clear that there is nothing logical in the proposed extension of the principle*" [italics ours],[11] does he not directly contradict the conclusions of Professor Greene and Professor Underwood? Furthermore, how are such views reconciled with the fundamental principle

[8] Pittonia 3: 128. 1896.

[9] Mem. Torr. Bot. Club 6: 247. 1899.

[10] Science 13: 588. 1901.

[11] Science 13: 588. 1901.

of the Rochester Code, and with the former statements of Professor Britton himself, who in 1890 emphatically argued of "priority of place," that "that is priority, I am sure"?

When the Rochester Code and its Madison amendments were put forward we were repeatedly told that their *raison d'être* was to establish our plant-names upon a permament basis. Therefore when the *Check List* was published it was naturally supposed that the names there included were final. At great inconvenience to all branches of American botany we have been forced, consequently, to stumble through a most perplexing tangle of ever-changing "permanent" names. If all this confusion and inconvenience were leading us by the shortest course —or by any course—to stability, no one but the short-sighted would complain. It is true that, in spite of their frequent changes from one policy to another, and notwithstanding the utter abandon with which they trifle with the most important principles, the reformers still claim to be bringing us uniformity. How can this be? Professor Underwood stands firmly for priority of place, claiming that the first species in the genus must be taken as the type. Professor Greene has taken the same ground, though openly arguing against some other principles of the Rochester Code. Now, after agitating for years the principle of strict priority and more than once defining his understanding of the term, Professor Britton has published an argument squarely opposed to the uniform acceptance of the first species of a complex genus as the type. Can it be, then, that with such hopeless diversity of opinion on the part of two leading reformers at the same university, they still have sufficient sense of humor to tell us that they are establishing uniformity? If Professor Underwood, following consistently the spirit and text of the Rochester Code, believes in changing "99 per cent." of names; and Professor Britton, abandoning the fundamental principle for which he has so long argued, changes names on a radically different basis, will they not give us systems of names more and more hopelessly unlike?

Professor Britton declares the position taken by Professor Underwood a "latter-day proposition," thus implying that the question of generic types was not seriously considered at Rochester and at Madison. Yet if the Rochester Code is the result of a "very careful consideration," how can this vital matter have been overlooked? However, the Rochester Code tells us that "priority of publication is to be regarded as the fundamental principle of botanical nomenclature,"

and Professor Britton has said "it is perfectly clear that as long as we allow ourselves a choice of names *in any way*, so long will authors differ in their acceptance and the settling of this important matter be deferred" [italics ours].[12] From these assertions the only logical conclusion is that doubtful cases are to be referred to the principle of priority. The decision between Buda and Tissa, and the determination of the generic type both "allow . . . . a choice of names," and according to the first principle of the Rochester Code priority alone should settle them. The question of Buda and Tissa is one of decision between two generic names for the same plant; the question of the generic type asks which of two or more plants shall bear a given generic name. When these questions have such fundamental similarity, how can a reformer maintain that priority is to decide in one case and not in the other?

When Professor Britton now maintains that the first species of a complex genus is not necessarily the type, and that in such cases the Rochester code allows us to cling to the traditional genera, he at once places himself on record as likewise opposed to the fourth rule of the Rochester Code. This rule reads:

IV. HOMONYMS.—The publication of a generic name or a binomial invalidates the use of the same name for any subsequently published genus or species respectively.

Let us look, for example, at the case of Mimosa, a name which Professor Britton and other reformers use in its traditional sense. The Linnæan Mimosa, published in the *Species Plantarum*, contained 39 species, the first on page 516, the last on page 523. Of these species only six are now retained in the genus as finally defined by Bentham in 1875 and now generally accepted. The first species now recognized in the Benthamian genus Mimosa is *M. viva*, no. 11 of the *Species Plantarum*. This species is the last one on page 517, and on that page it is preceded by six species, and on page 516 by four species, all of which are now treated as members of other genera. If Tissa has priority over Buda "for the simple reason that it stands first on the page," then surely by the same logic *Mimosa bigemina* and the other five species on page 517 have priority over *M. viva*. And still more clearly *M. viva* is preceded by *M. Lebbeck* (now treated as an Albizzia) and the other species on page 516. Mimosa was published on this page (516) of the *Species Plantarum* as the name of a

[12] Jour. Bot. 28: 372. 1890.

genus; then *M. Lebbeck*, *M. Inga*, *M. fagifolia*, and *M. nodosa* were published, not only with citations of their previous places of publication, but with brief diagnoses as well. Consequently the publication of the generic name Mimosa and the first of the species, *M. Lebbeck*, satisfies the Rochester requirement for the publication of a genus (see above). Furthermore, the species was treated as a Mimosa subsequent to its original publication in 1753, and it was first removed from the genus by Willdenow in 1806. Therefore, when the name Mimosa in the Benthamian sense is applied by Professor Britton to *M. viva* (and its congeners) while on a preceding page the same generic name had been applied to *M. Lebbeck*, a plant of different generic affinity, he uses a name which is a homonym.

Two fundamental principles of the Rochester Code are thus deserted by the chairman of the Rochester committee on nomenclature, while strongly defended by only one of the original members. And now from Nebraska, which has not long been notable as the seat of ultra-conservatism, comes the announcement, in regard to the recent work of the only consistent member of the original committee, that "it shakes one's faith in the immutability of things to find old friends under unfamiliar names."[13]

The reformers wedded themselves to the principle of strict priority. At the start they ignored the reasoning of those who foresaw where it would lead them. They rushed headlong and short-sighted into the scramble for hidden and obscure names. For a short time they worked harmoniously. Then came misunderstanding and lack of unity. One member of the nomenclature committee disclaims "that there is any obligation to elevate varietal names to specific rank when the [aggregate] varieties themselves are thus promoted."[14] In so doing he opposes the rule of the *Check List* committee which says "that the original name is to be maintained whether published as species, subspecies, or variety." Another member stands for absolute priority and takes a course in which Professor Britton finds "nothing logical." The chairman of the committee now proclaims that priority of place (precedence) is not necessarily final. In so doing he opposes not only the first, but the fourth of the Rochester principles. To every logical and fair-minded scientist who will take the trouble to consider the question calmly and judicially, this woeful diversity in the practices of the committee must be apparent. No one can say

[13] Science **13**: 833. 1901.

[14] GREENE, E. L., Pittonia **4**: 253. 1901.

today where individual members of the *Check List* committee will stand tomorrow. They have forgotten or ignored the fact that the Rochester Code was to give us permanent names. They have made of it a "personal preference hit-or-miss system." In the words of one of their number, they are "openly at war with their own rules." Is this uniformity? Is this "the day of law"? Is this the high road to a stable nomenclature?

Do we sincerely want uniformity, or do we prefer the tangled results of individual interpretation? If the former ideal still appeals to us, why not abandon this restless pursuit of the will-o'-the-wisp? Why not honestly test the combined Berlin rule for genera and Kew rule for species? None of their opponents have given them a fair trial. Until they do can they really judge of their merits?—M. L. FERNALD, *Gray Herbarium, June, 1901.*

FLOWER VISITS OF OLIGOTROPIC BEES. III.

AMONG the oligotropic bees mentioned in BOTANICAL GAZETTE **28**: 36, 215, and **30**: 130, should be included: *Andrena krigiana*, which collects its pollen from *Krigia amplexicaulis; Entechnia taurea*, which is an oligotropic visitor of *Ipomoea pandurata:* and *Anthedon compta*, which gets its pollen exclusively from *Oenothera biennis.*

Species of Melissodes, which usually collect the fine pollen of Compositae, have their scopae dense and quite closely plumose. On the other hand, Emphor, Xenoglossa and Entechnia, which collect the large pollen grains of *Hibiscus lasiocarpus*, *Cucurbita pepo*, and *Ipomoea pandurata*, have their scopae quite loose and thinly plumose. The close relationship of Anthedon to Melissodes, and the fact that the male has quite plumose hairs on his hind tibiae, show that the scopae of the female have recently lost the barbs and have come to be composed of simple bristles. I have wondered why this was so, and have expected to find some peculiarity in the pollen which the bee collects. Now in *Oenothera biennis* the pollen grains are large, trilobed, and connected by cobwebby threads. This condition of the pollen makes the barbs unnecessary if they would not greatly interfere with the collection of this kind of pollen.

Andrena nasonii, mentioned in the first list, is not oligotropic.

In the *Fertilization of Flowers*, p. 570, in discussing the effect of conspicuousness of flowers in inducing insect visits, Müller says:

"The most important deduction to be drawn from them is, that in general anthophilous insects are not limited by hereditary instinct to certain flowers, but that they wander about getting their food on whatever flowers they find it. For if each insect had its own species of flower, as most caterpillars have their own particular food plant, the abundance of insect visits to the plant would not depend at all upon its conspicuousness." Then, after mentioning the case of *Andrena florea* and *Bryonia dioica*, etc., he says: "But these insects do not form 1 per cent. of all the species that I have observed, and even of these cases the restriction is only complete in two."

In my neighborhood, excluding the inquilines, which do not make nests, 30 per cent. of the bees are oligotropic.— CHARLES ROBERTSON, *Carlinville, Ill.*

CURRENT LITERATURE.

BOOK REVIEWS.

Latex and mucilage.

To THE already extensive literature of the laticiferous tissues, Molisch contributes an important addition,[1] differing from its predecessors in giving chief attention to the constitution, both organic and chemical, of the latex itself. In his investigations he used living material and fresh latex, as well as that which had been fixed and stained. Molisch has confirmed and extended the earlier observations of Treub, Johow, and Schmidt on the existence of a plasmic membrane and nuclei in the latex tubes, for demonstrating which he recommends *Euphorbia splendens* and *Poinsettia pucherrima*. He finds the membrane lining the latex vessel and constituting an inner living tube within which the latex is formed like the cell sap. Special examination of the nuclei shows that some nuclei are very different from those of ordinary plant cells, having characters not before known in nuclei of any plant or animal. Molisch calls them *Blasenkerne*. The granular nucleus seems to lie centrally or excentrically in a relatively large globular vacuole, but really the vacuole is in the nucleus, the nuclear sap filling the space between the nuclear material and the membrane. Nuclei of somewhat irregular form are also present. Various phenomena lead to the conclusion that the nuclear membrane is an independent, clearly differentiated organ.

Besides the nuclei there are imbedded in the plasma leucoplasts of different kinds. Some form the elongated starch grains; others ("proteinoplasts") produce proteid granules, a phenomenon which has recently been observed also by Heinricher in Lathraea. Crystals of proteids or proteid-like substances are also produced, not anywhere in the contents of the latex tubes, but by the agency of special plastids or of vacuoles. Molisch also finds elaioplasts and vacuoles responsible for the formation of oil drops.

Into the details of the chemistry of the latex we cannot follow the author. The latex he finds usually acid, rarely neutral, and never alkaline; calcium salts and chlorids are variable in amount; magnesium compounds are abundant and sometimes accumulate in extraordinary quantity; proteids and carbohydrates are so abundant that one must look upon the latex tubes as special reservoirs of these foods.

As the latex is an emulsion, the fine division and consequently great surface

[1] MOLISCH, HANS: Studien über den Milchsaft und Schleimsaft der Pflanzen. 8vo, pp. viii + 111, *figs.* 33. Jena: Gustav Fischer. 1901. *M* 4.

of its constituents probably facilitates the absorption of gases and metabolism generally, to an extent hitherto unnoticed. On the rôle of the latex the author promises further publication.

Because the mucilage tubes of the Liliaceae, Amaryllidaceae, and Commelynaceae are analogous to the latex tubes, Molisch has investigated them. He finds extraordinary nuclei in some of them — filaments 1500μ long by 0.1–0.3μ in diameter; also proteid crystalloids, starch, glucose, and tannins, as in latex tubes, besides a new body, luteofilin, which occurs as sphere crystals in the mucilage of many monocots.—C. R. B.

A manual of bacteriology.

In 1897, Frederick D. Chester published in the *Annual Report* of the Delaware Agriculture Experiment Station a preliminary arrangement of the species of the genus Bacterium. This work, rearranged and enlarged to include all the groups of bacteria, has now appeared in a valuable *Manual of determinative bacteriology*.[2] While not so voluminous as Migula's great work on systematic bacteriology, this book is by far the most complete classification in English, conprising descriptions of some 780 forms. The system of classification adopted, by means of which related forms may be readily traced out or new species identified, is the same as that first proposed by Migula in Engler and Prantl's *Natürlichen Pflanzenfamilien* (1896), with some minor modifications. In the synopsis of Bacterium and Bacillus, coloration by Gram's method is used as an important differential test. This might be open to criticism, for variation of the Gram staining reaction within a so-called group is well known. It was brought out in a recent study of *B. pyocyaneus* by Roger C. Perkins as follows: "In reactions of the various organisms to Gram's stain, my results did not coincide with those of Jordan and Ruzicka, who note complete decolorization in every case. Of ten varieties studied in this present series, seven decolorized uniformly and regularly when treated by this method, but three retained the color at every trial."[3] On the other hand, Chester has given a subordinate place to formation of gas in the different sugar bouillons, a comparatively constant reaction.

In the section devoted to the terminology of descriptive bacteriology, the author has arranged and illustrated an excellent series of simple terms, capable of expressing definitely in one word the meaning of several sentences of the old style verbose and figurative cultural description. These terms are interesting additions to the bacteriological vocabulary. The criticism of species nomenclature is a point well taken, although no adequate suggestion is made as to how names of forms so closely related as the various kinds of

[2] CHESTER, FREDERICK D., A manual of determinative bacteriology. 8vo, pp. vi + 401, *figs. 13*. New York: The Macmillan Co. 1901. $2.60.

[3] Jour. Med. Research 281. 1901.

fluorescent bacteria could be made indicative of that fact and yet avoid the trinomial term. What faults may be found in the book, however, are of minor importance in comparison with its value as a reference book, and a supplement to the text-book of every student in a bacteriological laboratory.—MARY HEFFERAN.

The flora of Alabama.[4]

DR. CHARLES MOHR has left behind him a most substantial monument. The bulky volume before us contains the botanical records of "forty years of sojourn and wanderings" through the state of Alabama. It may be added that the "wanderings" were by no means aimless, but were those of a keen and tireless observer. Such a mass of observations by a single man is the possession of no other state. It is a pleasure to note that the author was permitted to complete the organization of his notes of a lifetime into permanent and usable form.

The book presents the patient study of a great and interesting area, not by the perfunctory cataloguing of species collected, but by the discussion of the broad biological features which have determined the flora and its distribution. The author evidently fully appreciated the newer aspects of the problems of floras, and has presented to us, in terms of Merriam's life zones and Warming's plant associations, the general ecologic and floristic features of Alabama.

The general discussion occupies 137 pages, and is full of material for the student of phytogeography. After some preliminary historical material, in which the work of such pioneers as Bartram, Buckley, Gates, Peters, Beaumont, and Nevius, are fully noted, the general physiographic features of the state are presented under topography and geology, river systems, and climate. Then follows an account of the general principles of plant distribution, the significance of life zones and of plant associations and formations being explained. These principles are then applied to the flora of Alabama, which is presented in its general character and distribution.

The ecologic relations are considered under the following titles: forest flora, open land or campestrian flora, water and swamp flora, organotopic flora (epiphytic, saprophytic, parasitic, and insectivorous plants), and introduced plants and their influence upon native plant associations. The distribution falls naturally under the two general heads of the Carolinian and Louisianian areas; the former including the mountain region, the table-lands of the Warrior and Coosa basins, the region of the Tennessee river valley, and the region of the lower hill country; the latter including the region of

[4] MOHR, CHARLES: Plant life of Alabama. An account of the distribution, modes of association, and adaptations of the flora of Alabama, together with a systematic catalogue of the plants growing in the state. Contrib. U. S. Nat. Herb. 6: 1–921. *pls. 1–13*. 31 Jy. 1901.

the central pine belt, the central prairie region, and the maritime pine region.

The systematic catalogue occupies 682 pages, and is a model of painstaking care in the way of bibliography, synonymy, and range. The thallophytes number 1722, and notably full is the list of fungi by F. S. Earle, and the list of lichens. The bryophytes number 166, the pteridophytes 109, the gymnosperms 13, the monocotyledons 681, and the dicotyledons 1782. The total enumeration of species and varieties is 4473. About ten new species are described, but very many described elsewhere are founded on Dr. Mohr's material. The three endemic species are *Trichomanes Petersii*, *Croton Alabamensis*, and *Neviusia Alabamensis*. The sequence is that of Engler and Prantl, and the nomenclature is that of the Rochester code.

It is a matter of great regret that the author was not spared long enough to receive the congratulations of his associates upon the appearance of his monumental work.—J. M. C.

Methods in plant histology.[5]

AS STATED in the preface, this work has grown out of a course in histological technique given by the author to his classes in the University of Chicago and to its non-resident students taking work in this subject through the Extension Division. A series of articles on the same subject published by the author in the *Journal of Applied Microscopy* forms the basis of the present volume.

The first part of the book, about one-third, is devoted to the discussion of apparatus, reagents, and most of the important methods of killing and fixing, staining, sectioning, and mounting plant tissues and the lower forms of plant life. The chapter on apparatus is short, and much could be introduced that would enable the student who has not a complete laboratory equipment before him to save time and material and also produce more perfect results. The chapter on reagents seems unnecessary, as most of the matter is repeated elsewhere in the book. The description of the paraffin method is most complete and very carefully prepared, while the treatment of the celloidin method is hardly adequate, and does not give the more recent improvements that contribute so much to the successful use of this method in plant histology. The treatment of the methods of killing, fixing, and staining is admirable.

Part II is devoted to the study of types of the various groups of plants systematically arranged and illustrated by specimens easily collected by any one familiar with the main divisions of the plant kingdom. The directions for the treatment of the material used in these studies are excellent, and the

[5] CHAMBERLAIN, CHARLES J.: Methods in plant histology. 8vo. pp. vi+159. *figs.* 74. Chicago: The University of Chicago Press. 1901. $1.50.

cimens judiciously selected. The treatment of the spermatophytes is the most comprehensive in the selection of material and in its preparation. The author, by his careful discussion of the various methods in the preparation of material emphasizes what is too often neglected in general histological studies, particularly of the lower forms, the careful preparation of material for examination. Much of the histological work with classes is misleading and useless because the teacher fails to appreciate this point. The student who learns to make a proper use of the best methods early in his course will be well repaid when at a later period he begins more critical studies. A convenient list of formulae for reagents is placed at the end of the volume.

The technique of the book is good, and the illustrations well selected, a few of them being photomicrographs of excellent preparations. The work is a most acceptable contribution to the growing list of laboratory manuals.—M. B. THOMAS.

MINOR NOTICES.

JAMES R. GOW[6] has published a preliminary list of the flowering plants of Adair county, Iowa.

WILDEMAN and DURAND[7] have issued a further publication on the Congo flora. It consists of the first fascicle of an enumeration of plants collected by Alfred Dewèvre in 1895–6 in the state of Congo, and contains from Ranunculaceae through Leguminosae, with descriptions of new species. A notice of the previous series may be found in BOT. GAZ. 31: 70. 1901.—J. M. C.

T. HEDLUND[8] has published a monograph of the genus Sorbus, which further rehabilitates a Linnean genus long included in Pirus. The author recognizes 58 species, and discusses them in great detail, with the help of text illustrations of venation, pollen grains, etc. He also includes subspecies and hybrids. Some ten or twelve North American species are involved.—J. M. C.

THE FIRST part of the second volume of Wiesner's *Rohstoffe des Pflanzenreiches* has just been issued.[9] It contains part of the seventeenth section on *woods*, newly elaborated by Dr. Karl Wilhelm with the assistance of Dr. S. Zeisel, who contributes the chapter on the chemistry of wood. The structure of woods and their physical and chemical qualities are described in 51 pp., followed by a synopsis (90 pp.) of the more important plants whose wood

[6] Proc. Iowa Acad. Sci. 8: 1–8. 1901.

[7] Annales du Musée du Congo. Botanique. III. Reliquiae Dewevreanæ. Fasc. 1. Bruxelles, May, 1901.

[8] Monographie der Gattung Sorbus. Kongl. Svenska Vetensk.-Acad. Handl. 35: 1–147. 1901.

[9] WEISNER, JULIUS: Die Rohstoffe des Pflanzenreiches. Versuch einer technischen Rohstofflehre des Pflanzenreiches. Second ed. Lieferung 6. 8vo. pp. 1–160. Leipzig: Wilhelm Engelmann, 1901. *M*5.

is used in the arts. A seventh chapter (incomplete) is to describe the microscopic characters of the most widely used woods.—C. R. B.

THE LAST ISSUE of the *Minnesota Botanical Studies* (2 : 537–655. 1901) contains the following papers: E. M. FREEMAN, "A preliminary list of Minnesota Uredineae," a little over 100 species being included; DEALTON SAUNDERS, "A new species of Alaria," from the Californian coast; F. K. BUTTEN, "A preliminary list of Minnesota Xylariaceae," including 19 species; W. A. WHEELER, "A contribution to the knowledge of the flora of the Red river valley in Minnesota," 325 species being listed, with eight excellent heliotype plates of plant formations; H. B. HUMPHREY, "Observations on *Gigartina exasperata* Harv.," a histological study, with one heliotype plate; W. G. FANNING, "Observations on the algae of the St. Paul city water;" W. A. WHEELER, "Notes on some plants of Isle Royale;" D. LANGE, "Revegetation of Trestle island;" J. C. ARTHUR and E. W. D. HOLWAY, "Violet rusts of North America," with one plate; H. L. LYON, "Observations on the embryogeny of Nelumbo" with three plates, reviewed in the BOTANICAL GAZETTE for October.—J. M. C.

THAT FIRES are not always so detrimental as they seem is disclosed by a reading of the second edition of the phytogeography of Nebraska.[10] The first edition has been reviewed in this journal,[11] and a statement as to the new material is all that is needed here. A comparison of the two editions shows that the entire book has been essentially revised and brought up to date, although the table of contents reads much the same in the two editions. Among the more important additions are a full discussion of methods for the determination of the frequence and abundance of species, a brief treatment of the primitive flora of the great plains, and the treatment of floral and vegetation elements and of accessory biological characters. Throughout the detailed chapters on the formations, much new material, the result of three years' further labor, is added. In the review of the first edition, the importance of this contribution to ecological workers was stated. Now that the book has been in actual use for four years, it is possible to speak yet more highly of its value. It is not too much to say that it is the most important and valuable work that has yet appeared in the field of American phytogeography.—H. C. COWLES.

NOTES FOR STUDENTS

S. YAMANOUCHI[12] has described and figured bodies in the dividing pollen mother cell of *Lilium longiflorum*, which stain deeply, are centers of radia-

[10] POUND, ROSCOE, and CLEMENTS, FREDERIC E.—The phytogeography of Nebraska. I. General Survey. 8vo. pp. 442, with four maps. Lincoln, Nebraska: The University Publishing Co. 1900. Second edition.

[11] BOT. GAZ. **25** : 370. 1898.

[12] Einige Beobachtungen über die Centrosomen in den Pollenmutterzellen von *Lilium longifolium*. Beihefte Bot. Centralbl. **10** : 310–303. *pl. 1.* 1901.

tion, and come to occupy a position at the poles of the nuclear spindle. He regards them as undoubtedly centrosomes.—J. M. C.

MISS MARIA DAWSON reports the results of three years' experimentation to determine the economic importance of nitragin, the commercial culture of the nodule organisms of Leguminosae. Her conclusion is "that for peas grown upon ordinary garden soil, peat, clay, or loam inoculation with nitragin is useless and superfluous, whilst upon gravelly soils a small increase in crop results from its use."[13]—C R. B.

ELIZABETH DALE[14] has studied the aerial tubers which are often very prominent in species of Dioscorea, notably *D. sativa*, in which they are said to become six or more inches in diameter. A study of their origin seems to indicate that they are stem structures, with conspicuous powers of propagation. In fact, the author ventures the statement that "the abundant formation of auxiliary tubers in many species of Dioscorea seems as if it were connected with the fact that these plants do not appear to form seed readily."—J. M. C.

DUSÉN has studied the byrological collections of the Swedish polar expedition under Dr. A. G. Nathorst in 1899. The localities visited on east Greenland extend from Pendulum island (74° 40′ N.) to Cape Stewart (70° 30′ N.), about 150 miles north and south of Cape Parry. The island of Jan Mayen was also visited. In this work he has had the assistance of Dr. H. W. Arnell on Bryum and Plagiobryum, and of Herr C. Jensen on Dicranum and Sphagnum. *Bryum subnitidulum*, *B. Dusenii*, *B. minus*, *B. Groenlandicum* and *B. Jan Mayense* are described by Arnell as new species, and the sporophyte of *B. obtusifolium* is fully described for the first time.[15]—C. R. B.

IT WAS OBSERVED by Sachs that when orthotropous roots, not too young, are inverted, they do not return to the vertical but become plagiotropous. Němec finds a satisfactory explanation[16] of this in the alteration of the receptive apparatus described in his previous paper,[17] thus confirming his views as to the nature of the perceptivity of typical roots, as well as Noll's idea, arrived at from theoretical considerations, that alterations in the response to directive stimuli have their source in an alteration of the receptive structure. He has observed, coincident with this induced plagiotropism, a change in the topographic relations of the quality of the sensitive plasmic layer. The difference between the original and the newly assumed structure is just the

[13] Annals of Botany **15**: 511–519. 1901.

[14] On the origin, development, and morphological nature of the aerial tubers in *Dioscorea sativa*. Ann. of Bot. **15**: 491–501. *pl. 26*. 1901.

[15] Bihang till Svenska Vet. Akad. Handl. **27**: 1–71. *pls. 4*. 1901.

[16] Berichte deutsch. bot. Gesells. **19**: 310–313. 1901.

[17] Jahrb. f. wiss. Bot. **36**: 80. 1901. See also BOT. GAZ. **32**: 145. 1901.

difference between that found in orthotropous roots and normally plag otropous ones.—C. R. B.

A SHORT TIME since reference was made in this journal to the question of nomenclature in phytogeography.[18] It is interesting to read in this connection the translation of Professor Flahault's address at the Paris Congress[19] of 1900. While many may object to the arbitrary usage of the various terms suggested by Flahault, all will agree that the general questions at issue are made clearer, and we shall await the more impatiently the final decision of a competent committee. It seems questionable to the reviewer, however, whether the nomenclature problem can be settled by a committee, or even a convention. An arbitrary set of terms often acts to prevent a real advance of knowledge, if strict adherence is given to them. Already the terms zone, region, and association have rather definite meanings in the minds of active phytogeographers. Even the much vexed word "formation" is being more commonly used in the original and broader sense, as more inclusive than the word "association." Perhaps other terms also will become more definite in a perfectly natural way.—H. C. COWLES.

W. H. LANG in a late paper[20] has given a preliminary account of some experimental work on wild plants of a species of Anthoceros, in which he has demonstrated that by mutilating very young unopened sporophytes and bringing the cut surfaces in contact with soil under certain conditions of moisture, temperature, and light, bud-like outgrowths are produced from the vegetative cells that lie between the sporogenous region and the external layer. The cells in this region are the least specialized of all in the capsule. They become to some degree isolated in position by the decay of the surrounding tissue. The general sequence of the early divisions in the cells giving rise to the so-called prothallial growths are said to be "closely parallel to the early stages of germination of the spores of Anthoceros." His cultures were carried no further than to the production of a "bud-like stage," which produced rhizoids. The result would he more convincing if he had obtained flat prothallia bearing reproductive organs. This is the first discovery of apospory recorded for any liverwort, although found in a number of mosses and ferns.—FLORENCE M. LYON.

THE IMPORTANT WORKS of Stahl and of MacDougal and Lloyd on mycorhiza have been reviewed in this journal.[21] Mention should also be made of the work of Hesselman[22] on the mycorhiza of arctic plants. Boreal forms

[18] BOT. GAZ. **31**: 361. 1900. [19] Bull. Torr. Bot. Club **28**: 391–409. 1901.

[20] On apospory in *Anthoceros laevis*. Ann. of Bot. **15**: 503–510. *pl. 27*. 1901.

[21] BOT. GAZ. **30**: 68. 1900.

[22] Bihang till K. Svensk. Vet. Akad. Handl. **26**:—. 1900. (See Bot. Centralb. **86**: 239. 1901.)

been but little studied in this connection, and it might be supposed that the more xerophytic climatic conditions would work against the root fungi. Many plants, however, are found to possess mycorhiza in considerable abundance. Salix, various ericads, Dryas, Diapensia, and other species appeared much like more southern forms. W. Magnus has made an important cytological contribution[23] to the mycorhiza literature. He finds that the endotropic mycorhiza of Neottia is of two types, which differ in position, structure, and function. Four to six layers of cells immediately within the exodermis contain fungal hyphae. In the outer and inner layers of these cells the hyphae are thin-walled, and the fungi are digested by the host plant; ultimately the fungal threads degenerate, forming masses which also contain parts of the cell protoplasm. These masses Magnus regards as excreted products. In contrast to the above the more centrally located hyphae are thick-walled and remain vigorous throughout, not being digested by the host; these hyphae have haustoria and are regarded as parasitic on the orchid. This study thus gives still another view as to the significance of endotropic mycorhiza. Magnus treats in detail the cytology of the hypertrophied host cells, and at the close of the paper gives an excellent bibliography of the mycorhiza literature.— H. C. COWLES.

ITEMS OF TAXONOMIC interest are as follows: E. L. GREENE (Pittonia 4:285–320. 1901) has described 17 new species of Viola, 12 of Cerastium, 5 of Rumex, 8 of Lesquerella, 3 of Draba, and 7 of Lacinaria.—J. K. SMALL (Torreya 1:73–75. 1901.) has discussed Juncoides in the southeastern states, describing a new species; has described (*idem* 97) a new Crataegus from Florida; also (*idem* 107–108) a new Chamaelirium; and (*idem* 67) a new Alleghanian Rudbeckia.—E. P. BICKNELL (*idem* 102–105) has described 2 new eastern species of Lespedeza.—B. D. GILBERT (Fern Bull. 9:53–54. 1901) has described a new Asplenium from Kamchatka.—F. S. EARLE (Muhlenbergia 1:9–17. 1901) has written upon some fungi from Porto Rico, describing 11 new species and 1 new genus (*Cercosporidium*) of the Dematiaceae.—W. N. SUKSDORF (Bot. Monatss. 19:91–93. 1901) has described new species of Sisyrinchium, Potamogeton, Juncus, Deyeuxia, Melica, and Equisetum, from Washington.—THEO. HOLM (Ottawa Nat. 15:110–111. 1901) has described 3 new Canadian species of Gentiana.—WILDEMAN and DURAND (Bull. Herb. Boiss. II. 1:839. 1901) have described a new genus (*Bosqueiopsis*) of Urticaceae from the Congo region.—SCHMIDLE and WELLHEIM (*idem* 1007-1012, *pl. 13*) have described a new genus (*Rhodoplax*) of Pleurococcaceae.—H. MIEHE (Ber. deut. bot. Gesells. 19:434–441. *pl. 21*. 1901) has described a new genus (*Crapulo*) of marine Flagellates.—J. MATSUMURA (Bot. Mag. Tokyo 15:67. 1901) has described a new Formosan genus (*Alniphyllum*) of Styracaceae.—G. LOPRIORE (Malpighia 14:435 and

[23] Jahrb. für wiss. Bot. 35: 205–272. 1900.

448. 1901) has described two new African genera (*Argyrostachys* and *Sericostachys*) of Amarantaceae.—H. and P. SYDOW (Hedwigia Beibl. **40**: 62–65. 1901) have described a new African genus (*Hapalophragmium*) of Uredineae.—FR. FEDDE (Engl. Bot. Jahrb. **31**: 30–133. 1901) has taken up the Nuttallian genus Mahonia, recognizing 37 species, 7 of which are new.—SCHMIDLE (*idem* **30**: 246, 247, and 253) has described two new African genera (*Myxoderma* and *Chondrogloea*) of Stigonemataceae, and a new African genus (*Chaetonella*) of Cladophoraceae.—J. K. SMALL (Bull. Torr. Bot. Club **28**: 356-361. 1901) has described 8 new shrubs and trees from the southern states, and also a new genus (*Brayodendron*) to include *Diospyros Texana*; and has also (*idem* 451-453) discussed *Dasystoma flava* and some related species, describing two as new.—R. M. HARPER (*idem* 454–484) has described new species of Rhynchospora, Viola, Dicerandra, and Baldwinia, from Georgia.—V. S. WHITE (*idem* 421–444. *pls. 31–40*) has published a revision of the Tylostomaceae of North America, describing 10 new species and including one new genus (*Dictyocephalos*) described by L. M. Underwood.—P. A. RYDBERG (*idem* 499–513), in continuing his studies of the Rocky mountain flora, has published new species of Trifolium, Vicia, Primula, Cuscuta, Monarda, Castilleia, Pentstemon, Sambucus, and of 9 genera in the Compositae.—GEORGE MASSEE (Jour. Linn. Soc. **35**: 90–118, *pls. 4–5*. 1901) has published the second part of his redescriptions of Berkeley's types of fungi, including all the species of Discomycetes and Hysteriaceae of which type specimens exist at present in the Kew herbarium.—J. M. C.

NEWS.

DR. ROLAND THAXTER has been promoted to a professorship of cryptogamic botany at Harvard University.—*Science.*

WE REGRET to announce the death of the young English phycologist William West, who died in India, from cholera, at the age of twenty-six years.

AN EXCELLENT biographical sketch and portrait of the late Dr. Charles Mohr appear in the September number of *Plant World.* It is written by Professor S. M. Tracy.

DR. A. F. W. SCHIMPER, professor of botany in the University of Basle, and widely known for his monumental *Pflanzengeographie*, died on September 9, in his forty-sixth year.

IN THE OCTOBER number of the *Journal of Applied Microscopy* there is an interesting illustrated account of the botanical laboratory and gardens of the Tokyo Imperial University, by Kiichi Miyake.

A BIOGRAPHICAL SKETCH of Professor T. C. Porter, with an excellent artotype portrait, was published in the July number of the *Bulletin of the Torrey Botanical Club*, having been prepared by Dr. N. L. Britton.

MISS S. M. HALLOWELL, professor of botany at Wellesley College, has been given leave of absence for the year, and the work of the department will be under Miss Clara E. Cummings, assistant professor of botany.—*Science.*

WE HAVE LEARNED that the herbarium of Theodor von Heldreich, professor of botany and director of the Botanic Gardens, Athens, is for sale. It contains approximately 20,000 species, and richly represents the floras of Greece, Asia Minor, and Egypt. It contains also hundreds of types and authentic specimens of new species described by Heldreich in the works of Boissier.

PROFESSOR ALEX. P. ANDERSON, formerly in charge of plant physiology in the University of Minnesota, has been appointed Curator of the herbarium of Columbia University, to fill the position made vacant by the appointment of Dr. Howe to the Garden staff. Professor FRANK S. EARLE, formerly of the Alabama Polytechnic Institute, has been appointed assistant curator in charge of the collection of fungi at the New York Botanical Garden.

AN ACCOUNT of the opening of the new botanical department at Glasgow University appears in the *Annals of Botany* for September last. It was a part of the celebrations on the ninth jubilee of the university, and the open-

ing address was made on June 13, by Sir Joseph Hooker, whose father had been for twenty years the professor of botany at Glasgow. He was followed by Lord Lister and Professor Bayley Balfour in proposing a vote of thanks for the address.

AT THE DENVER meeting of the Botanical Society of America a committee, consisting of Drs. Trelease, Britton, and Robinson, was appointed to investigate and report upon the condition of the National Herbarium. The following resolution was passed: "That it is the present policy of the society to accumulate invested funds until the annual income, interest and dues, is at least $500, and then to use such income yearly, or at greater or less intervals, as circumstances may dictate, for the best advancement of botanical knowledge."

THE SUBJECTS for the Walker prizes in Natural History for the next two years have been announced. For 1902 the botanical subject is "Nuclear fusions in plants," besides a general subject entitled "The reactions of organisms to solutions, considered from the standpoint of the chemical theory of dissociation," which may just as well be competed for by a plant physiologist. For 1903 the subject is "A monograph of any genus or group of thallophytes." For detailed information as to the conditions of competition address Glover M. Allen, Secretary, Boston Society of Natural History, Boston, Mass.

THE EXECUTIVE COMMITTEE of the 11th Congress of Naturalists and Physicians has asked that the following announcement be made: The Congress will convene at St. Petersburg on January 2, 1902, and continue until January 12. General sessions will be held January 2, 8, and 12; and sectional meetings on the other days, botany constituting a distinct section. Those wishing to be present as members should send their names and addresses, with the membership fee (3 roubles), also indicating their section, to the Executive Committee of the Congress, University, St. Petersburg, not later than December 15.